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**US Army Corps  
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Engineer Research and  
Development Center

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# **An Overview of Jefferson Proving Ground UXO Technology Demonstration (Phase III) Contractor Performance Self-Assessments**

*by John O. Curtis*

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by John O. Curtis

Environmental Laboratory  
U.S. Army Engineer Research and Development Center  
3909 Halls Ferry Road  
Vicksburg, MS 39180-6199

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# Preface

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Phase III of a series of unexploded ordnance (UXO) detection and discrimination technology demonstrations was conducted at the Jefferson Proving Ground (JPG), IN, during the fall of 1996. Twelve contractors performed these demonstrations for the U.S. Army Environmental Center (AEC), Aberdeen Proving Ground, MD, under the overall management of Ms. Kelley Rigano.

As part of the evaluation of Phase III results, four contractors conducted critical self-assessments of their sensor and data processing performance at the request of the U.S. Army Engineer Research and Development Center (ERDC) at Vicksburg, MS. These contractors were provided with ground truth information on emplaced UXO and nonordnance items after all twelve contractor performances had been scored by AEC. The principal investigators for all ERDC efforts associated with the Jefferson Proving Ground UXO technology demonstrations were Dr. Ernesto R. Cespedes, ERDC, Environmental Laboratory (EL), and Dr. Dwain K. Butler, ERDC, Geotechnical Laboratory (GL).

This report, which represents a distillation of the four contractor self-assessments, as well as ERDC contributions to the issue of magnetic signature modeling, was written by Dr. John O. Curtis , EL, under the oversight of Drs. Cespedes and Butler. Dr. Janet E. Simms, GL, contributed the prolate spheroid magnetic signature model simulations discussed within.

At the time of publication of this report, general supervision was provided by Mr. Norman R. Francingues, Chief, Environmental Engineering Division, EL, and Dr. John W. Keeley, Director, EL. The Commander of ERDC was COL Robin R. Cababa, EN.

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# **1 Introduction**

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## **Background**

Because of downsizing of our military forces brought on by changing world politics, modernization of forces, and economic pressures, many military facilities that have been used for decades as aerial bombing ranges and other weapon systems training ranges are being closed. There is a huge demand to return these properties to the public sector for multiple uses. Before that can be done, the land must be cleared of all unexploded ordnance (UXO). The millions of acres involved and the great depth of burial for the largest of these UXO items, along with the fact that the UXO lie among great quantities of exploded ordnance, preclude the safe and cost-effective use of hand-held magnetometer devices to locate the explosive devices and men with shovels to dig them up.

In FY93 Congress funded the first of a series of UXO Technology Demonstrations to be conducted at Jefferson Proving Ground (JPG), in Madison, IN. One of the objectives of these demonstrations was to evaluate sensor systems that might be capable of cost-effectively detecting and discriminating (among the large amount of metal debris) UXO at all possible depths and orientations. The third of these demonstrations (Phase III) was conducted in the fall of 1996 (AEC 1997).

Phase IV of the JPG Technology Demonstrations focused primarily on the use of sensor technologies to discriminate UXO from nonordnance items. However, it also included a science and technology program, managed by personnel at the U. S. Army Engineer Research and Development Center (ERDC), in Vicksburg, MS, whose goals included an assessment of Phase I-III results, a characterization of the JPG sites, and the conduct of phenomenological modeling. One element of the science and technology program involved the performance of critical self-assessments by several of the Phase III demonstrators. This report consolidates and embellishes on those self-assessments.

## **Jefferson Proving Ground UXO Technology Demonstrations Phase III Synopsis**

The Phase III demonstrations were performed by twelve contractors using ground-based sensor systems at a sixteen-hectare test site. Both surrogate UXO (hereafter referred to as ordnance) and non-ordnance items were buried in four distinct areas of the test site. Each area and its accompanying ordnance items is referred to as a scenario and represents a general class of targets. Table 1 is a summary of the four scenarios offered to the demonstrators at JPG, Phase III. A plan view of the distribution of each type of ordnance is shown in Figure 1. Each scenario included about four hectares of area. Scenario 4, the Interrogation and Burial Area, was unique in the sense that the target locations were provided to the demonstrators. Their task, if they chose to participate in Scenario 4, was to characterize the buried targets. Characterization of subsurface

anomalies, as described in the AEC Phase III final report (AEC 1997), involved three elements: (a) typing, or declaring an anomaly to be either ordnance or nonordnance, (b) sizing, or identifying the principal diameter of the ordnance item to be either small (less than 100 mm), medium (between 100 and 200 mm), or large (greater than 200 mm), and (c) classifying, or declaring the ordnance to be a bomb, projectile, mortar, submunition, or rocket. Each demonstrator examined a set of 20 assigned targets in Scenario 4, 17 of which were ordnance items.

**Table 1**  
**JPG Phase III Scenarios**

	<b>Range of Ordnance Size</b>	<b>Maximum Search Depth</b>	<b>Number of Ordnance Items</b>	<b>Number of Non-Ordnance Items</b>
<b>Scenario 1 Aerial Gunnery</b>	2.75 in rockets to 2000 pound bombs	3 meters	43	78
<b>Scenario 2 Artillery and Mortar</b>	60 mm mortars to 8 in projectiles	1.2 meters	67	50
<b>Scenario 3 Grenade and Submunition</b>	as named; possibility of larger ordnance	0.5 meters	98	39
<b>Scenario 4 Interrogation and Burial Area</b>	complete range of sizes	2 meters	53	72

## **Contractor Self-Assessment Goals**

In February of 1998, a Request for Proposals (Appendix A) was issued by the US Army Engineer District, Vicksburg, MS, in which the Phase III demonstrators were asked to perform a critical self-assessment of their performance during the demonstrations. The selected contractors were to be given the Phase III ground truth data and asked to address the issues of why ordnance items were missed in their original analysis of data and why some non-ordnance items were declared as ordnance. Suggested issues included sensor sensitivity, reliability, and threshold levels chosen for accepting data as well as navigation and positioning errors of the sensor systems. Beyond those issues, the Request for Proposals called for "explanations and mitigating factors" for errors in properly distinguishing ordnance from non-ordnance items.

The four contractors chosen for this critical self-assessment were ADI Limited, of East Sydney, NSW, Australia, ENSCO, Inc., of Springfield, Virginia, Geo-Centers, Inc., of Newton Centre, Massachusetts, and Geophysical Technology Limited (GTL), of Armidale, NSW, Australia (which was known as the Geophysical Research Institute, or GRI, during the Phase III demonstrations).

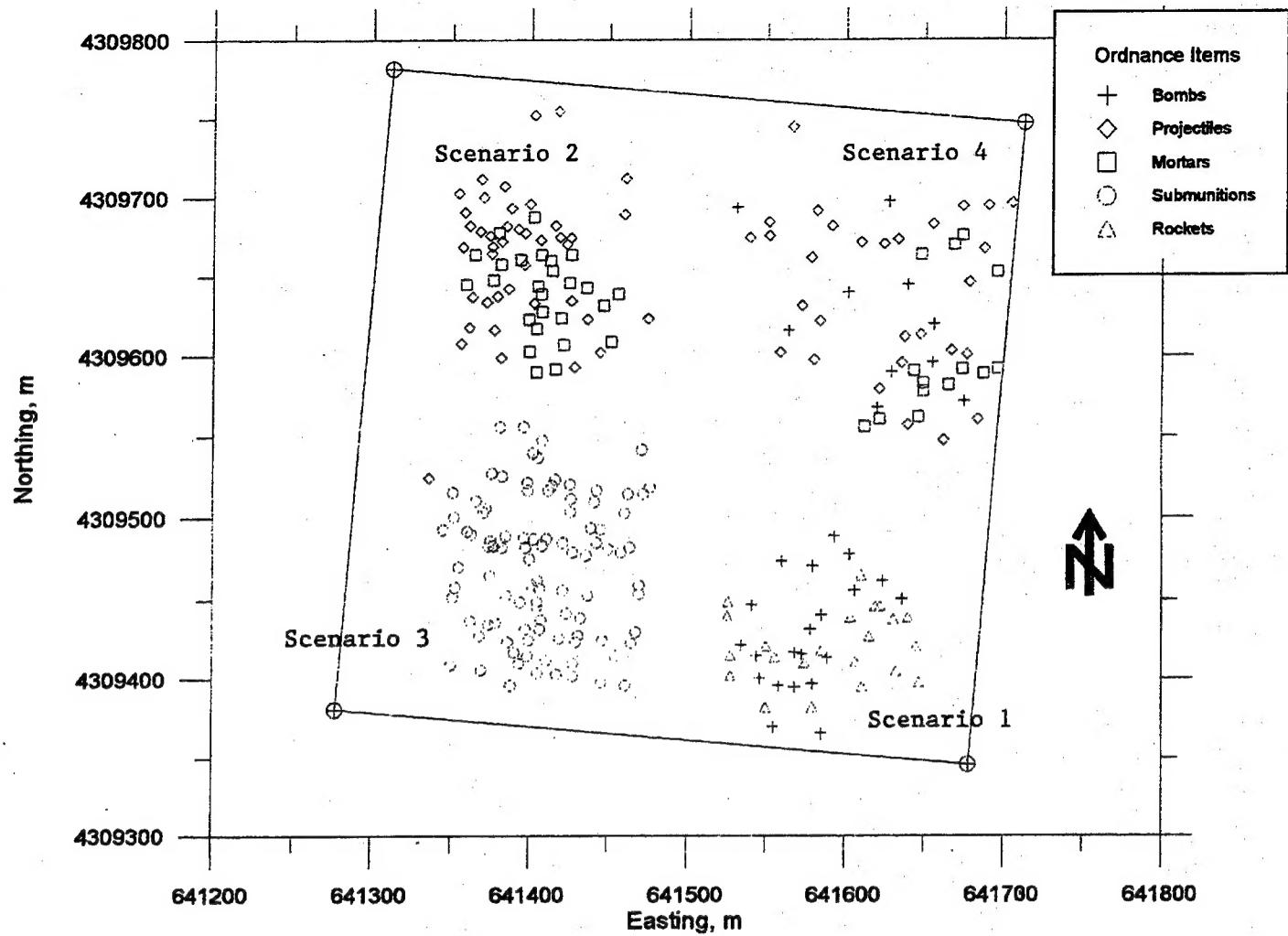


Figure 1. Plan view of the JPG Phase III test site (Llopis 1999)

## **ERDC Objectives**

The Advanced Technology Demonstrations at JPG were scored by the coordinating agency simply by the number of ordnance items declared as ordnance by the demonstrator as hits, and all other declarations as misses (which erroneously includes non-ordnance items declared as non-ordnance). The ERDC objective of having contractors perform self-assessments was to learn why ordnance items were missed, why items were declared improperly, and whether or not shortcomings were related to data processing, or sensor performance, or site geophysics, or target signature uncertainty. Some of the questions that ERDC engineers and scientists hoped to answer by this exercise included:

- Was the correct sensor technology being used, or was it being properly utilized?
- If different contractors used the same technology, what caused their performance to be different?
- How significant were the chosen sensor thresholds?
- What was the impact of data manipulation schemes?
- What was the impact of the human factor in determining performance?
- If target signature models were used for identification/classification, were they found to be adequate?
- Is enough known about basic target signatures for different sensors to use models?
- Are the models sophisticated enough to be applied to the Phase III data?
- What lessons were learned from the Scenario 4 measurements?

## **2 Discussion**

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Each of the four contractors who performed self-assessments produced two reports, one containing a description of what they did during the Phase III demonstrations, and one containing their explanations for missed ordnance and improperly declared ordnance. Rather than redistribute these reports (which, in some cases, are quite extensive) to interested parties, only those portions of the contractor reports that discuss missed targets are reproduced in the appendices. The following sections are an attempt to condense the contractor self-assessments into as few words as possible, while still providing a means of addressing some of the questions raised in the previous chapter.

### **Sensor Technology and Performance Statistics**

Table 2 contains a brief summary of the sensor technologies utilized by these four contractors along with their performance in Phase III as scored by the federal government's project coordinator (AEC 1997). Performance numbers are averages for all of the scenarios for which each contractor chose to make measurements and report ordnance and non-ordnance items. Those scenarios are identified in the table. There was nearly universal agreement among the contractors that a combination of magnetometer and electromagnetic induction (EMI) sensor technologies is needed to produce the best target detection statistics.

It is especially interesting to note that ADI and GTL used identical magnetometer equipment, but produced quite different performance statistics. This observation indicates that data collection procedures, the use of other instrumentation, how data are machine processed, and how humans enter the evaluation process, must all play a significant role in demonstration results. For example, one finds from reading the self-assessment reports that magnetometer elevation was different for the two contractors and that data spacing (see Table 3) was also different for scenarios 2 and 3. ADI made use of four magnetometer sensors. In Scenarios 2 and 3, the four units were spaced 25 cm apart in a horizontal arrangement. The height of the sensors above the ground surface was maintained at about 20 cm. For Scenario 1, two of the sensors were elevated above the other two; however, there was no indication in the self-assessment reports that the Scenario 1 data were processed in a gradiometer mode. GTL also used four magnetometer units but kept them in a horizontal arrangement with a 50 cm horizontal spacing and an elevation above the ground surface of about 65 cm. Therefore, for Scenarios 2 and 3, it is likely that ADI's spatial data density and depth of penetration should be greater than those of GTL. These and other factors, such as the use of different EMI devices, undoubtedly contribute to generating different performance statistics.

**Table 2**  
**Contractor Sensor Technologies and Performance Statistics**

	Sensor Technology	Performance Statistics (AEC 1997)
<b>ADI</b>  <b>mag in Scenarios 1,2,3</b>	TM-4 total field magnetometers 0.01 nT resolution, lower sensors 20 cm above ground, upper sensors in Scenario 1 were 60 cm above the lower, noise floor 0.2 nT	Probability of Detection = 0.78 (note 1)  False Alarms/Hectare = 109.5 (note 2)  False Alarms/Detected Ordnance = 8.3
	Geonics EM-61 time-domain EMI 1 meter square coils, 20 cm vertical separation, lower coil 25 cm above ground, single time window (modified for ADI)	
<b>ENSCO</b>  <b>Scenarios 1,2</b>	Schonstedt GA72CD vertical-component gradiometers, unknown resolution	Probability of Detection = 0.70  False Alarms/Hectare = 48.7  False Alarms/Detected Ordnance = 5.1
	White Instruments Spectrum XLT metal detector used to relocate some targets in Scenario 2	
<b>Geo-Centers</b>  <b>Scenarios 1,2,3</b>	Geometrics 822A total field magnetometers, 4 lower mags 15 cm above ground, 4 upper mags 38 cm above lower mags, 1/3 nT resolution	Probability of Detection = 0.93  False Alarms/Hectare = 81.8  False Alarms/Detected Ordnance = 5.2
	Geonics EM-61 time-domain EMI 0.5 meter coils, 50 cm vertical separation, lower coils 6 in above ground	
<b>GTL (formerly GRI)</b>  <b>Scenarios 1,2,3</b>	TM-4 total field magnetometers 0.01 nT resolution, 65 cm above ground	Probability of Detection = 0.93  False Alarms/Hectare = 240.5  False Alarms/Detected Ordnance = 15.2
	Minelab F1A4 multi-period, time-domain EMI, single 18 in diameter coil, avg 10 cm above ground, 1 emu resolution	

note 1: Probability of detection is the number of baseline ordnance targets reported by a demonstrator divided by the total number of baseline ordnance targets.

note 2: False alarms are any targets reported by a demonstrator that do not correspond to baseline ordnance targets. This includes non-UXO items reported as non-UXO items.

## Data Collection and Processing

The spatial density of data collected by each contractor and the pre-decision-making processing of those data should be important factors in determining contractor performance. Table 3 contains a summary of these elements and reveals that data spacing is comparable for all four demonstrators. However, insufficient information is available in the self-assessment reports to fully comprehend how much and what type of processing was done on the data before ordnance/non-ordnance decisions were made. For example, while it is clear that each demonstrator filtered their data profiles to remove noise and to enhance target signatures, very little information on what kind of filters were used, what sort of coefficients were applied, etc. From the information given, it is not possible to speculate whether or not real target signatures may have been lost due to preprocessing techniques, nor was that information offered by the demonstrators.

<b>Table 3</b> <b>Data Collection and Processing Methodologies</b>		
	<b>Data Collection Methodology</b>	<b>Data Processing Methodology</b>
<b>ADI</b>	TM-4: 50 cm line spacing in Scenario 1 25 cm line spacing in Scenarios 2,3 10 cm along-line spacing  EM-61: 50 cm line spacing in Scenario 3 20 cm along-line spacing	TM-4: 101-point high-pass filter of each line to eliminate deep geological sources and diurnal effects; spline interpolations to produce smooth 3-D data surfaces with 10 cm spacing  EM-61: levelling of data to remove instrument bias and temporal variations; spline interpolations to produce 3-D data surfaces
<b>ENSCO</b>	3 ft (91 cm) line spacing 9 in (23 cm) along-line spacing	each line filtered with a 51-point median filter followed by a 5-point mean filter; the result is subtracted from the raw data to eliminate any time-varying trends; 3-D grid of each Scenario generated using Surfer Contouring Program
<b>Geo-Centers</b>	50 cm line spacing (both mag and EMI) 11 cm along-line spacing (mag) 22 cm along-line spacing (EMI)	temporal correction of mag data by subtracting base station data; data interpolated to a 10 cm 3-D grid; no discussion of filtering
<b>GTL (formerly GRI)</b>	TM-4: 50 cm line spacing 10 cm along-line spacing  F1A4: 50 cm line spacing 5 cm along-line spacing	TM-4: temporal corrections by subtracting base station data; removal of single-value large amplitude spikes with low-pass median filter; spline interpolations used to produce smooth 3-D data surfaces with 25 cm spacing; removal of deep geological sources with high-pass median filter  F1A4: similar processing

## UXO Detection and Discrimination Logic

The ultimate objective of all of the JPG UXO Technology Demonstrations is to find a method of detecting and discriminating UXO from man-made and/or natural clutter. Table 4 contains a brief description of each demonstrator's techniques for performing this task. Clearly, the state-of-the-practice in target detection is visual identification and correlation of magnetometer and EMI sensor data maps. Some of the reasons for this may be an indication of a lack of confidence in the preprocessing of data, or the models used (if used at all) to determine target characteristics, or some combination of those factors.

**Table 4**  
**Detection and Discrimination Logic**

	<b>Detection Logic</b>	<b>Discrimination Logic</b>
<b>ADI</b>	visual identification of apparent magnetic dipole anomalies above a 2 nT threshold; if the dipole is distinct, then the object is declared an ordnance item; EMI data used to locate anomalies in x-y plane	compare measured data to dipole field superimposed on earth's field to provide an estimate of depth, mass, and orientation; mass used to classify as submunitions, mortars, rockets, projectiles, and bombs
<b>ENSCO</b>	visual identification of magnetic data anomalies; depth estimation from an in-house code that related depth to half-width of the anomaly	insufficient information in reports; could be primarily human experience
<b>Geo-Centers</b>	visual identification of magnetic anomalies (typically greater than + or - 10 nT); EMI data used for depth estimates and identification of non-ferrous targets	dipole field superimposed on earth's field to estimate location, size, depth, and angular parameters; gradient data and model used for further refinement and resolution of compound objects; analyst's experience was critical
<b>GTL (formerly GRI)</b>	visual identification of magnetic data anomalies; automated identification of EMI anomalies supported by human checks	simple dipole fits to anomalies followed by ellipsoidal object model fits to data; comparison of EMI data to existing data base of target responses; human fusion of the two studies using a particular set of rules

In addressing the question of models and their applicability to the task of discriminating UXO from non-UXO, consider the total magnetic field anomaly data for scenario 1 as presented by one of the demonstrators (GTL 1998) and reproduced in Figure 2. Yellow, orange, and red colors depict positive magnetic anomalies, with red representing values greater than 70 nT. Green, blue, and violet colors signify negative anomalies, with violet representing values less than -110 nT. Clearly, the figure contains several magnetic dipole-like measurement patterns. Most of these responses have had placed next to them a number or the letter "N". The number is a key number for a baseline ordnance item. "N" signifies that the response is from a non-ordnance item, but not necessarily something implanted by the demonstration coordinator. The ordnance items are described in Table 5. Burial depth refers to the shortest distance from the ground surface to any surface of the buried item. Dip is defined as the angle below the local horizontal ground plane, and azimuth is assumed to be the clockwise angle from true north.

The first observation that one can make from Figure 2 is that there must be some permanent magnetization associated with many of the baseline ordnance items. The rationale for making this statement is as follows. If the items were truly demagnetized before burial, then they would all acquire an induced dipole that would produce a magnetic anomaly with a high on the south side of the object and a low on the north side. Rotation of the semimajor axis of the ordnance item would result in some rotation of the axis of the induced dipole as shown in Figure 3 for a series of simulations of an unmagnetized prolate spheroids (Altshuler 1996). As an elongated ferrous object rotates in any plane that forms an angle with the earth's magnetic field, the direction of the induced dipole will also rotate (but lag) until it reaches a maximum value of something on the order of 50 degrees from the geomagnetic direction.

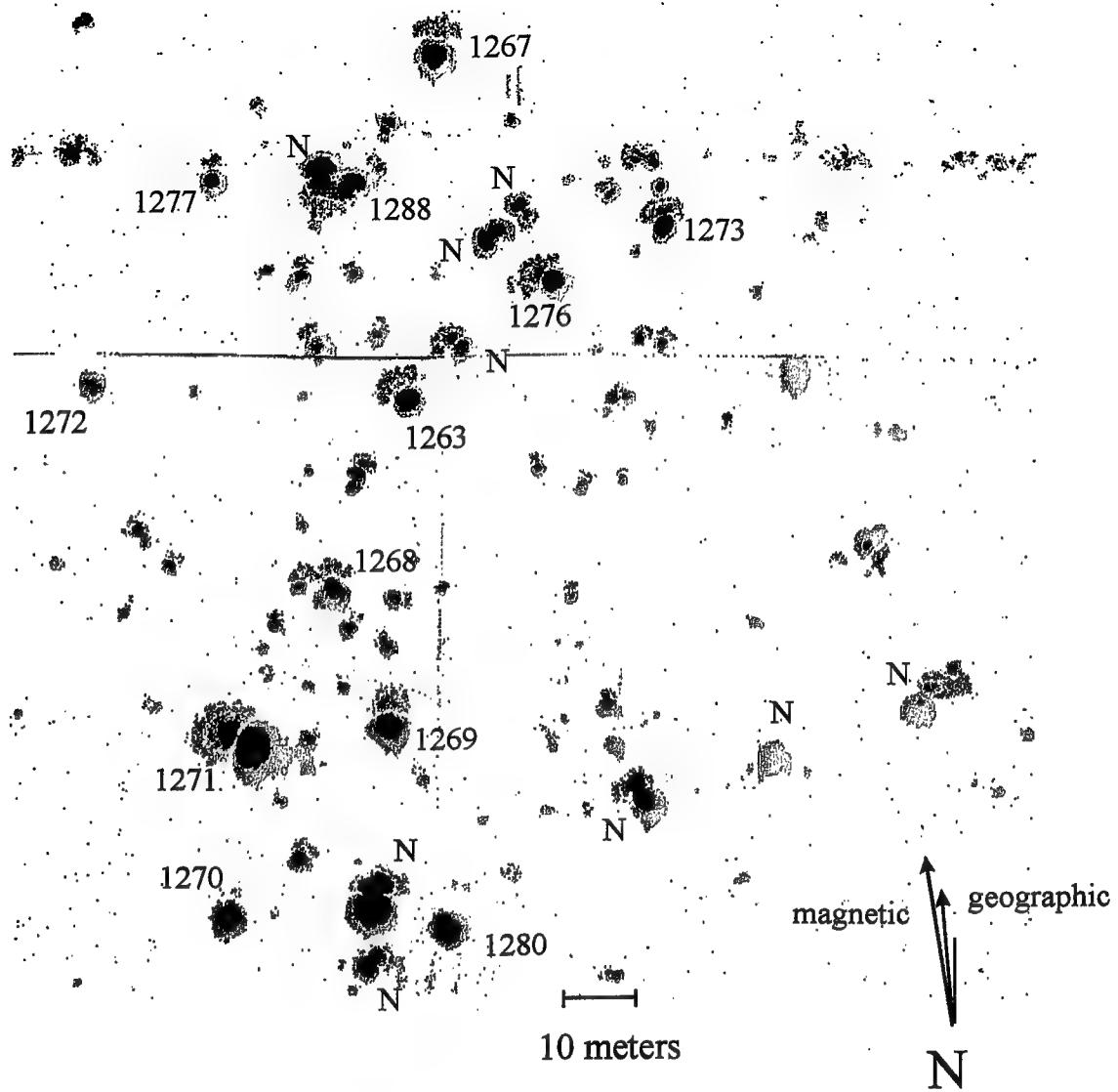


Figure 2. Total magnetic field anomalies within scenario 1 (GTL 1998)

**Table 5****Figure 1 Ordnance Item Descriptors (Scenario 1) For Figure 3 Data**

<b>Item</b>	<b>Serial No.</b>	<b>Description</b>	<b>Northing Easting (m)</b>	<b>Depth (m)</b>	<b>Dip (deg)</b>	<b>Azimuth (deg)</b>	<b>Predicted Dipole Rotation From Geomagnetic Direction</b>	<b>Measured Dipole Rotation From Geomagnetic Direction</b>
1263	K0012	500 lb bomb Mk82	4309441.149 641585.025	0.98	0	45	40	-17
1267	K0009	500 lb bomb Mk82	4309489.282 641593.148	1.85	0	45	40	7
1268	P0011	250 lb bomb Mk81	4309416.325 641572.820	1.65	0	0	4	1
1269	K0015	500 lb bomb Mk82	4309396.829 641579.544	1.44	0	0	4	2
1270	L6001	750 lb bomb M117	4309370.452 641554.945	1.87	0	45	40	9
1271	K6001	500 lb bomb Mk82	4309395.597 641558.123	1.7	0	315	-35	-64
1272	P0006	250 lb bomb Mk81	4309446.608 641540.944	1.82	45	45	40	Monopole
1273	P0002	250 lb bomb Mk81	4309462.468 641623.558	0.32	0	45	40	1
1276	P0004	250 lb bomb Mk81	4309455.791 641606.195	0.65	0	90	4	-58
1277	P0007	250 lb bomb Mk81	4309474.100 641560.040	1.28	0	0	4	5
1280	K6002	500 lb bomb Mk82	4309365.792 641585.428	1.9	45	225	40	Monopole
1288	BB6009	25 lb bomb Mk76/BDU33	4309471.260 641579.529	0.27	0	45	40	50 (reversed polarity)

From the azimuth values of ordnance items listed in Table 5 a column (second from the right) of predicted dipole axis rotations was added using the model results of Altshuler. The azimuth angle is assumed to be relative to geographic north, while the dipole rotation is given with respect to magnetic north. As an example, item 1263 was supposed to have been oriented at an angle of 45 degrees clockwise from geographic north. At JPG that would be about 49 degrees from magnetic north, which would result in a predicted dipole rotation of about 40 degrees clockwise from magnetic north. The GTL color maps were examined closely to obtain an approximate measured dipole orientation. Those numbers are listed in the last column of Table 5. Notice that item 1263 had a measured dipole angle of -17 degrees from magnetic north. In fact, only five of the twelve ordnance items listed in Table 5 had dipole responses that might have been predicted by a model. Perhaps the strongest argument for permanent magnetization in the JPG Phase III ordnance items is found in the reversed polarity of item 1288 and its non-ordnance neighbor. Note also that the two items that were buried with a dip of 45 degrees to the horizontal displayed such weak dipole responses that they appear to be monopole in nature.

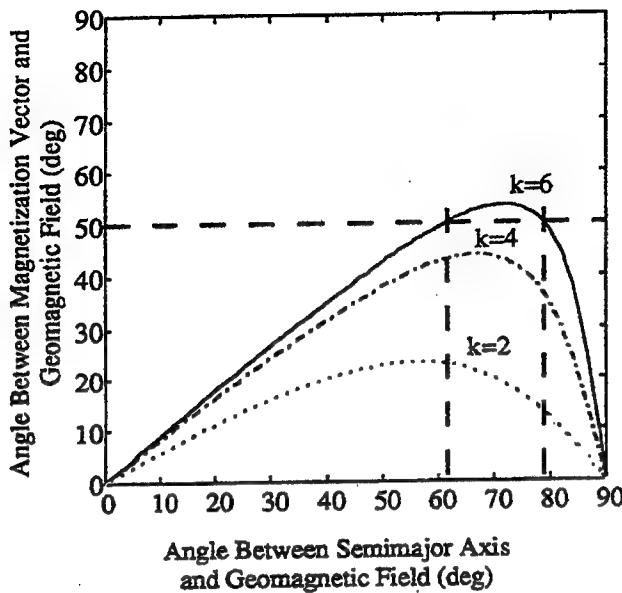


Figure 3. Prolate spheroid model predictions of induced magnetic dipole rotations  
(Altshuler 1996)

## Model simulations

Not only is there the issue of permanent magnetization of baseline ordnance to deal with in analyzing JPG Phase III magnetic data, but one must also ask whether or not the dipole models used by some of the demonstrators to help characterize targets would have had any utility even if the targets were demagnetized. Personal communications with two of the demonstrators (GeoCenters and ADI) indicated that a simple model of a magnetic dipole superimposed on the earth's field was used to derive an estimate of target size and orientation from the total field anomaly data.

To explore the question of whether or not a simple superimposed dipole could be useful in characterizing subsurface UXO, a spreadsheet model was developed to calculate the total field anomaly produced by such a dipole. In the following paragraphs, these simulations will be compared to a more rigorous prolate spheroid model and then, as a check against reality, they will be compared to the response of item number 1271 in Figure 2.

### A projectile rotated normal to the earth's field

**Prolate spheroid model.** Higher order models that include both dipole and octapole contributions for a prolate spheroid geometry have shown good correlation to measured data on real targets. One such model, developed at ERDC (Butler, et al 1998), was used to simulate the response of a 105 mm projectile as shown in Figure 4. The maximum diameter of this object was taken to be 11 cm, while its length was set equal to 42 cm. The distance from the body's center of mass to the total field instrument was chosen to be 1.43 m. The earth's magnetic field was

assigned a magnitude of 57000 nT, an inclination (dip in JPG Phase III terminology) of 70 degrees, and a declination (azimuth in JPG terms) of 0 degrees. There was no particular rationale for choosing these parameter values, except that they are nice round numbers that are somewhat representative of possible conditions somewhere in the Midwest of the United States. Finally, for the simulation results shown in Figure 4, the long axis of the projectile was assumed to be parallel to the earth's surface and rotated 90 degrees to the east of true north. In other words, the projectile was assumed to be lying east-west in the earth's magnetic field. As expected, the simulated anomaly is positive on the south side, with a maximum response of 14.45 nT, and negative on the north side, with a minimum response of -1.38 nT. Naturally, the object's response is symmetric about the north-south line through the center of mass.

**Simple dipole model.** The simple dipole superposition model requires the dipole moment strength and orientation as input in addition to the earth's field descriptors. This model assumes that the dipole is the dipole induced in a solid sphere by the earth's field. In MKS units, the magnetization, or magnetic moment per unit volume, induced in a sphere is (Jackson 1975):

$$\bar{M} = \frac{3}{\mu_0} \left( \frac{\frac{\mu}{\mu_0} - 1}{\frac{\mu}{\mu_0} + 2} \right) \bar{B}_0$$

where  $\bar{B}_0$  is the earth's field vector ('field' will be used in place of the proper term, 'induction'),  $\mu$  is the magnetic permeability of the sphere, and  $\mu_0$  is the permeability of free space, equal to  $4\pi \times 10^{-7}$  newtons/amp<sup>2</sup>. For a ferrous sphere, the induced magnetic dipole reduces to

$$\vec{m} = 0.01r^3 \bar{B}_0$$

where the units of the dipole are amp-m<sup>2</sup>, the earth's field is in nanotesla, and the radius of the sphere is in meters.

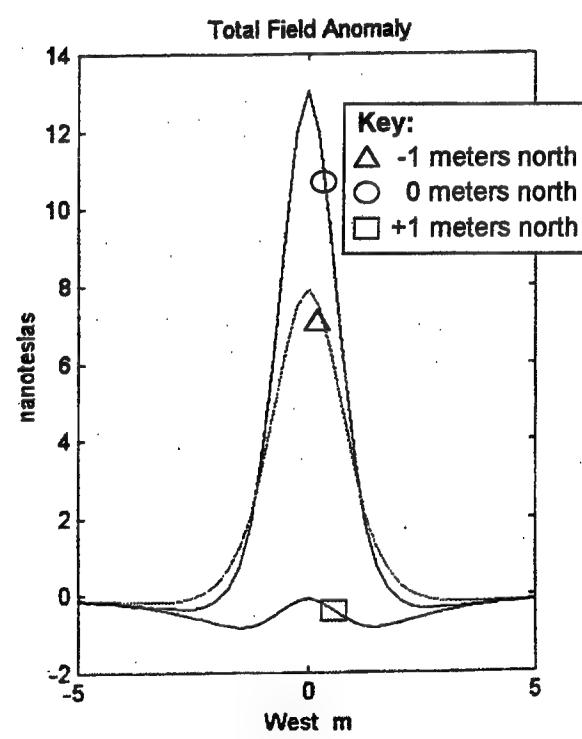
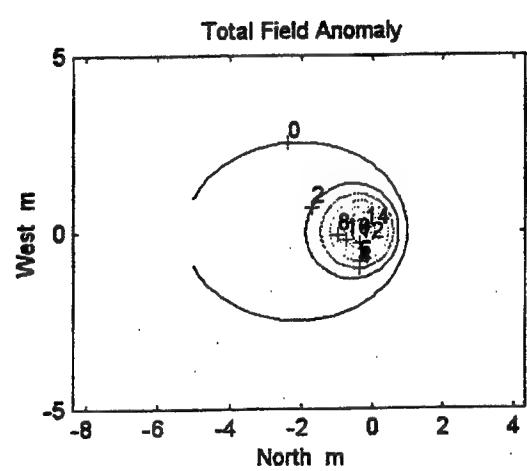
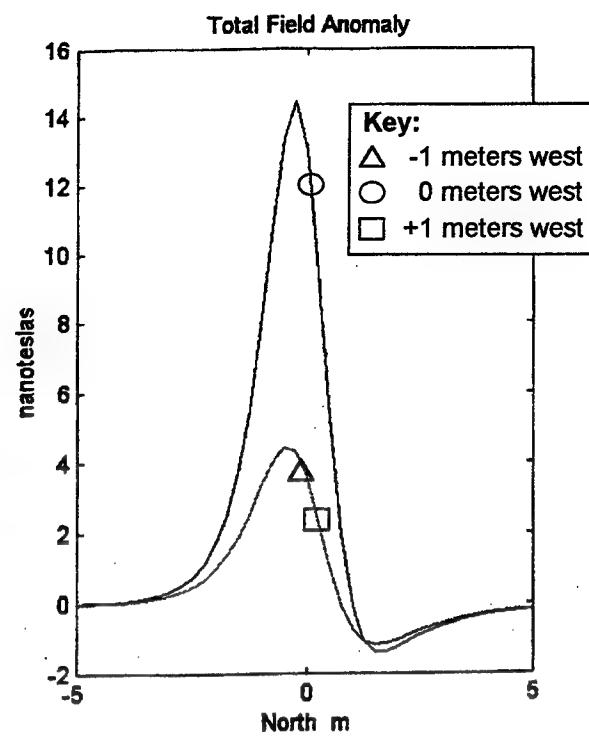
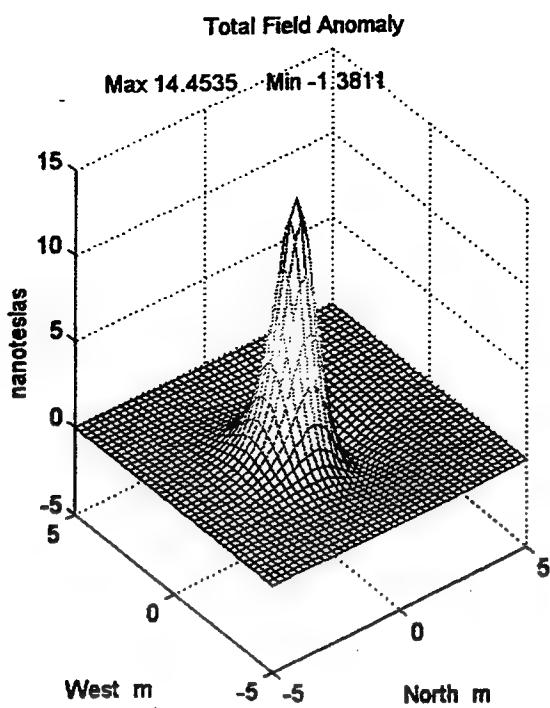


Figure 4. Prolate spheroid simulation of a 105 mm projectile (dip = 0 deg, az = 90 deg, depth = 1.43 m)

The dipole superposition model calculates the magnetic field of the dipole as the curl of a vector potential,

$$\vec{B} = \vec{\nabla} \times \vec{A},$$

and the potential is taken to be (Jackson 1975)

$$\vec{A} = \left( \frac{\mu_0}{4\pi} \right) \frac{\vec{m} \times \vec{r}}{r^3}$$

As a first approximation, the 105 mm projectile was taken to be a circular cylinder with a radius of 5.5 cm and a length of 42 cm. Of course, these dimensions result in a projectile volume much larger than that of the corresponding prolate spheroid, but it is a starting point. The volume of this cylinder is equivalent to that of a sphere of radius 9.84 cm, whose induced dipole is 0.543 amp-m<sup>2</sup>. Now, the first question to be answered is whether or not the simple superimposed dipole with the induced moment of an equivalent volume sphere results in a signature that looks anything like the prolate spheroid simulation. Figure 5 contains the 3-D anomaly plot of the induced dipole simulation which has an appearance similar to that of the prolate spheroid simulation in Figure 4. The earth's field parameters were identical in the two simulations, as was the height of the sensor above the object's center of mass. Clearly, the induced dipole gives a much stronger response, with the maximum value of the anomaly being 33.7 nT.

Assuming that the depth to the object is accurately known, then the only variable in the dipole simulation is the dipole strength. Through a trial-and-error procedure, a dipole of about 0.24 amp-m<sup>2</sup> (a sphere of radius 7.495 cm) was found to give a result almost identical to the prolate spheroid simulation. The results of the superimposed dipole model are depicted in Figure 6 in a format similar to the prolate spheroid model output. It is not coincidental that the prolate spheroid simulation generated an effective dipole moment of 0.237 amp-m<sup>2</sup>. The lesson to be learned from this simulation is that, given knowledge of the depth to the object, the dipole model would have underpredicted the volume of the object by about 56 percent.

It is extremely important to note that there is some important physics missing in the superimposed dipole model. It can not be used to predict object orientation if the object's long axis is rotated more than about 45 degrees from the earth's field. The dipole for the simulation results shown in Figure 6 was taken to be in the direction of the earth's field. But the major axis of the object being simulated was actually normal to the earth's field. As was stated earlier, the direction of an induced dipole in an unmagnetized ferrous object cannot be rotated much more than 50 degrees from the direction of the earth's field by rotating the object, even though the semimajor axis of the object may be normal to the earth's field. As can be seen in the superimposed dipole simulation results of Figure 7, it makes no sense to direct the dipole normal to the earth's field to correspond to the orientation of an actual object.

**total magnetic field less earth's field  
for a given magnetic dipole orientation**

earth's field (nT) = 57000

inclination of earth's field (degrees) 70

declination of earth's field (degrees) 0

dipole moment (amp-m<sup>2</sup>) = 0.543

rotation angle of dipole from x-y plane (degrees) 70

rotation angle of dipole from positive x axis (degrees) 0

magnetometer elevation above point dipole = -1.43

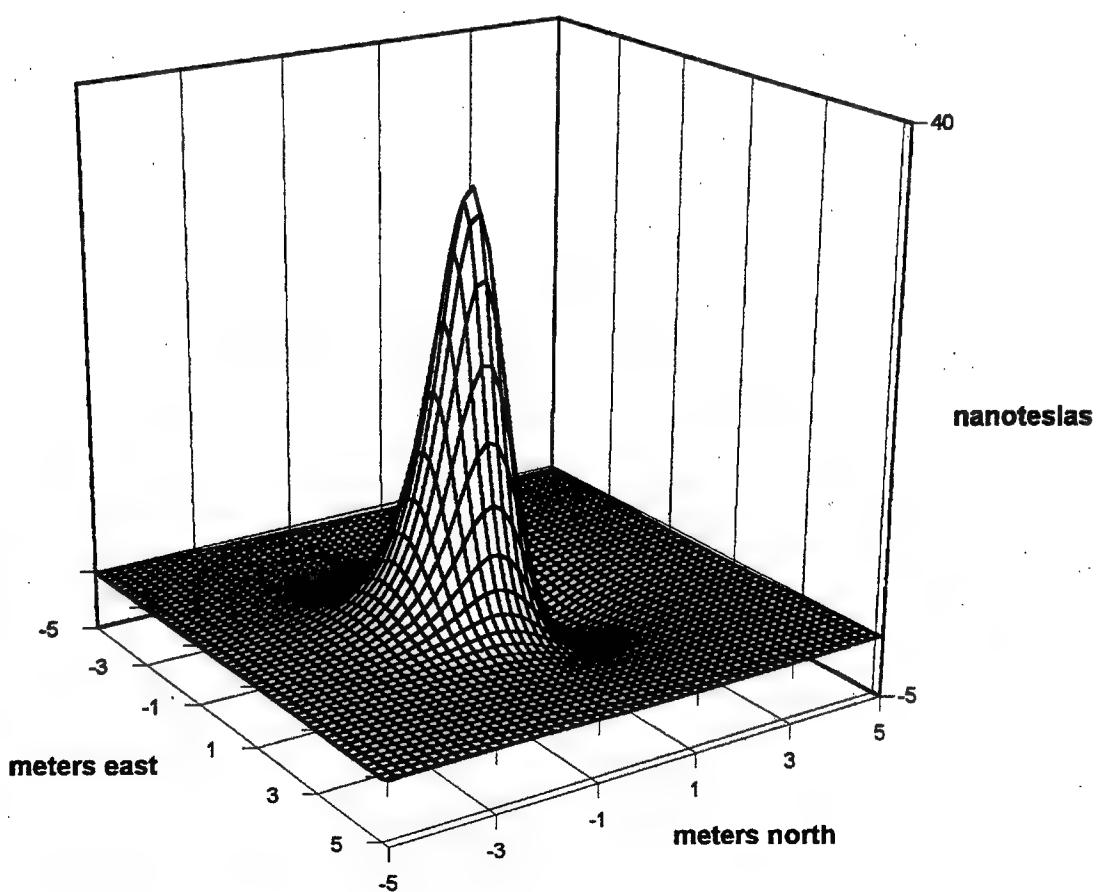


Figure 5. Induced dipole simulation of a 105 mm projectile (moment = 0.543 amp-m<sup>2</sup>, depth = 1.43 m)

**total magnetic field less earth's field  
for a given magnetic dipole orientation**

earth's field (nT) = 57000

inclination of earth's field (degrees) 70

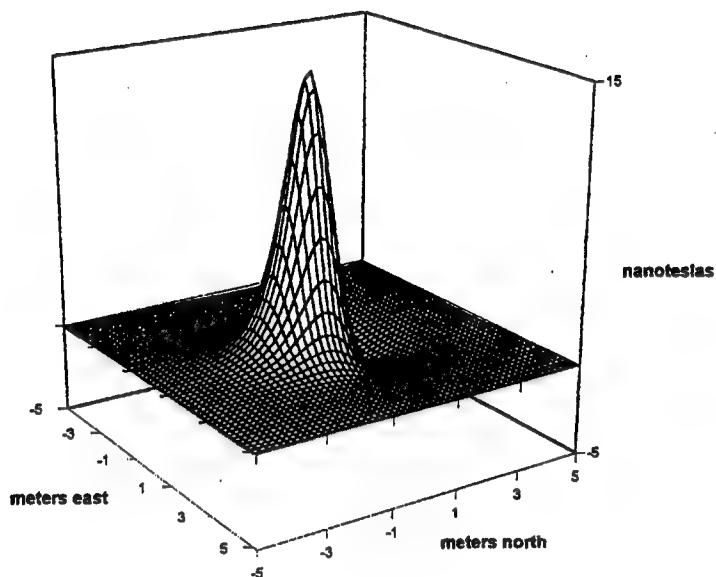
declination of earth's field (degrees) 0

dipole moment (amp-m<sup>2</sup>) = 0.24

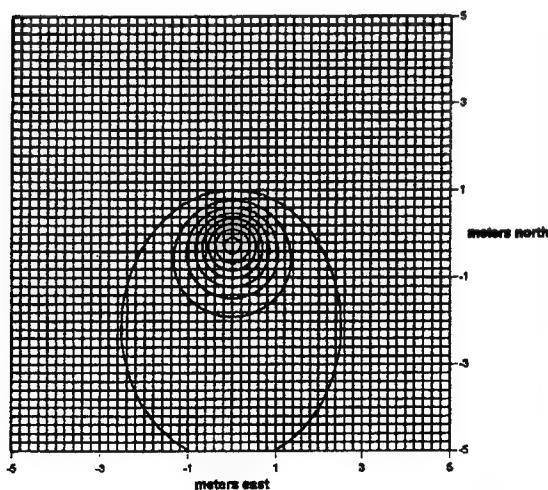
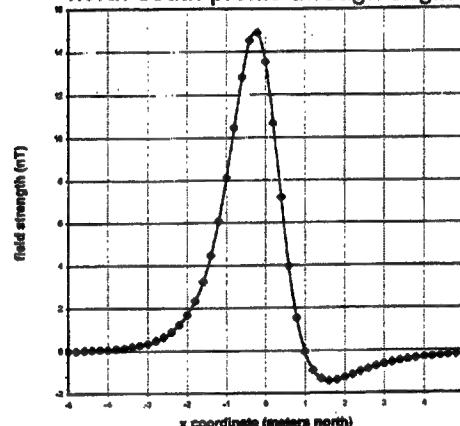
rotation angle of dipole from x-y plane (degrees) 70

rotation angle of dipole from positive x axis (degrees) 0

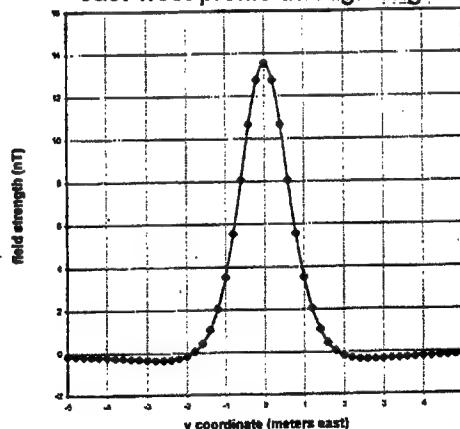
magnetometer elevation above point dipole = -1.43



**north-south profile through origin**



**east-west profile through origin**



**Figure 6. Induced dipole simulation of a 105 mm projectile (moment = 0.24 amp-m<sup>2</sup>, depth = 1.43 m)**

**total magnetic field less earth's field  
for a given magnetic dipole orientation**

earth's field (nT) = 57000

inclination of earth's field (degrees) 70

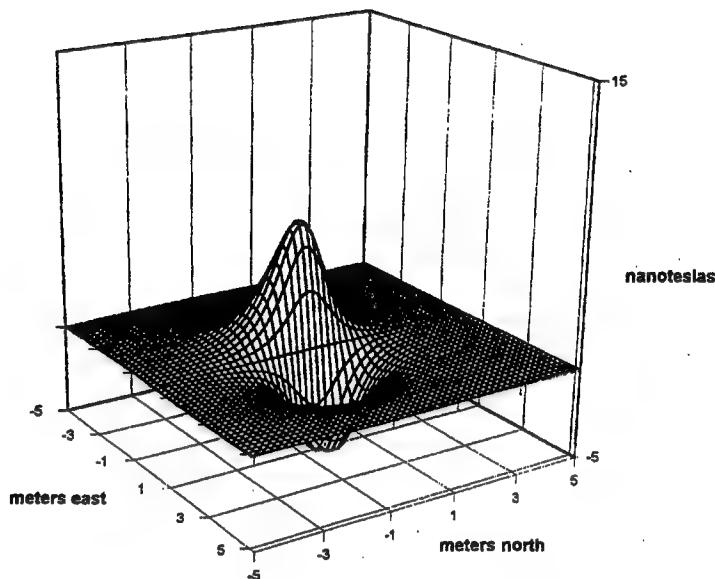
declination of earth's field (degrees) 0

dipole moment (amp-m<sup>2</sup>) = 0.24

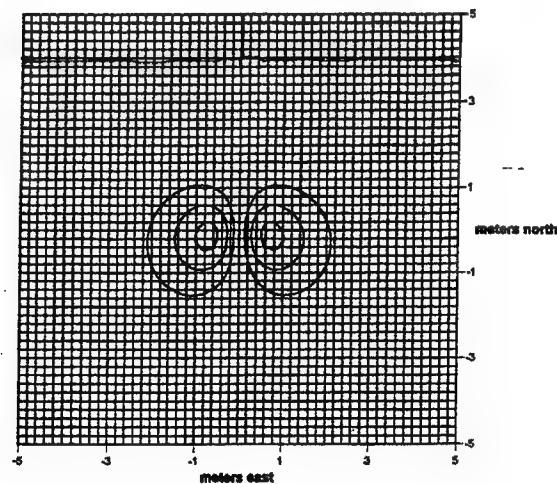
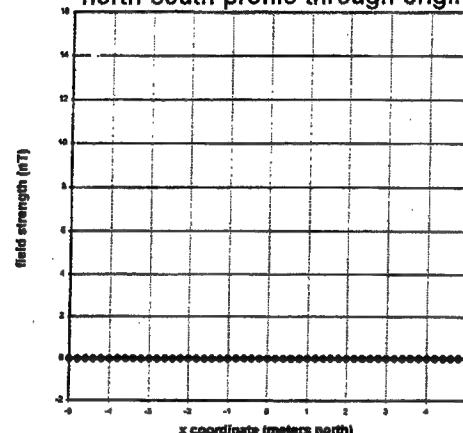
rotation angle of dipole from x-y plane (degrees) 0

rotation angle of dipole from positive x axis (degrees) 90

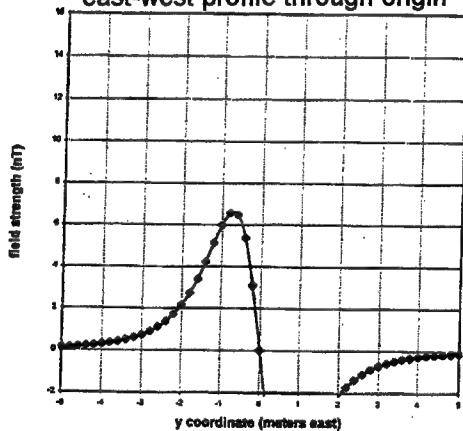
magnetometer elevation above point dipole = -1.43



**north-south profile through origin**



**east-west profile through origin**



**Figure 7.** Dipole simulation (moment = 0.24 amp-m<sup>2</sup>, dip = 0 deg, azimuth = 90 deg, depth = 1.43 m)

The simple superimposed dipole model can also generate an error in depth prediction. Let us assume that one is certain that only 105 mm projectiles are buried at a given site and that the magnetic dipole induced in those projectiles by the earth's field is  $0.543 \text{ amp-m}^2$ , and furthermore, that the maximum measured response to a buried projectile is 14.45 nT. Simply by running the dipole model with different sensor-to-object distances, one finds after several iterations that the depth to the object should be 1.88 m, which exceeded the actual depth by 31 percent. The results for this simulation are shown in Figure 8.

Note also that the character of the depth iteration simulation (Figure 8) is quite different from that of the prolate spheroid simulation (Figure 4). The dipole model results in a width of the anomaly at half of its maximum value of about 2 meters; whereas, for the prolate spheroid model, the half-max width is about 1.5 meters. If target characterization algorithms make use of such information, then the simple induced dipole model presents another opportunity for poor performance.

**total magnetic field less earth's field  
for a given magnetic dipole orientation**

earth's field (nT) = 57000

inclination of earth's field (degrees) 70

declination of earth's field (degrees) 0

dipole moment (amp-m<sup>2</sup>) = 0.543

rotation angle of dipole from x-y plane (degrees) 70

rotation angle of dipole from positive x axis (degrees) 0

magnetometer elevation above point dipole = -1.88

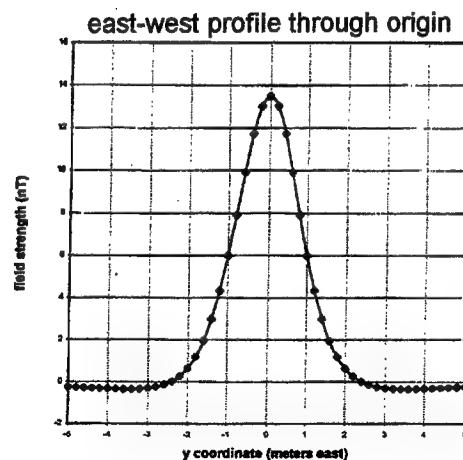
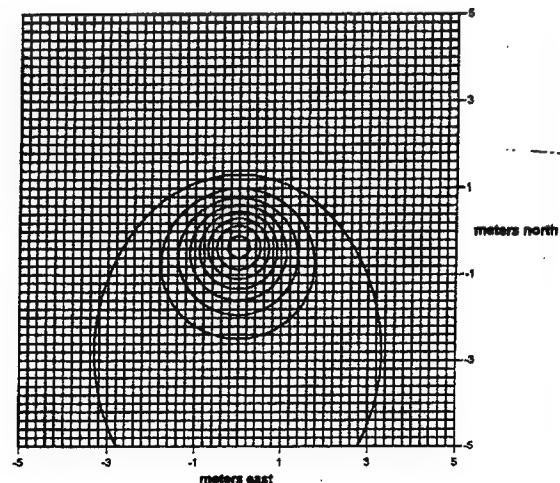
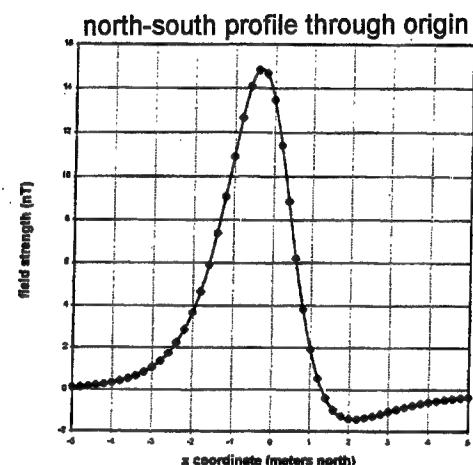
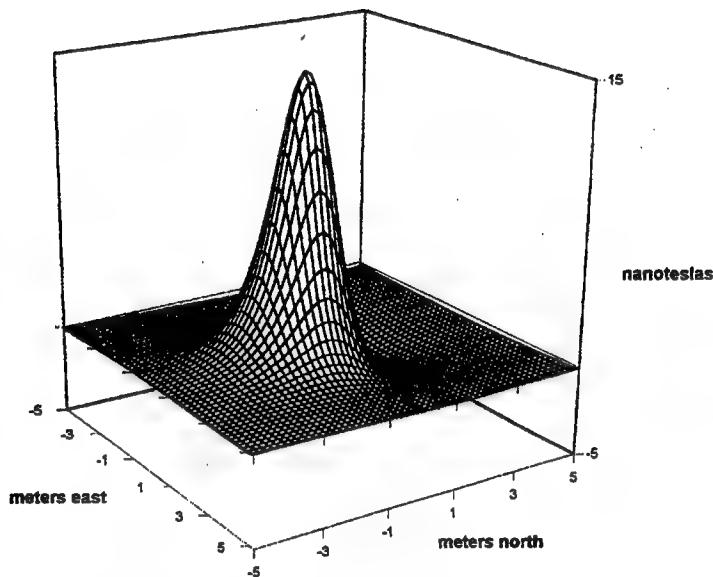


Figure 8. Results of varying depth to object for an induced dipole simulation of a 105 mm projectile (moment = 0.543 amp-m<sup>2</sup>)

## A projectile rotated at odd angles to the earth's field

**Prolate spheroid model.** A second prolate spheroid simulation was performed on the same 105 mm projectile, but this time the long axis of the object dipped 45 degrees below the horizontal, and was then rotated 90 degrees from the vertical plane passing through true north. The results of this simulation are shown in Figure 9. Note that the dipole-like response has been rotated about 45 degrees clockwise from true north and that the peak response is about 56.5 nT. The reason for the greater response by the simulated sensor is that the dip of the projectile caused a large portion of the object to be closer to the sensor, and the 1/distance<sup>3</sup> effect on the field becomes magnified in the closer mass.

**Simple dipole model.** A simple dipole simulation was also conducted with the goal of answering the question of whether or not dipole orientation can be meaningful and useful in predicting target orientation. It has already been established that simple dipole rotations of 90 degrees in azimuth produce meaningless results. Nevertheless, a dipole of strength 0.543 amp-m<sup>2</sup> was assigned a dip angle of 45 degrees and an azimuth rotation of 90 degrees. Surprisingly, the character of the modeled response was similar to that of the prolate spheroid, but the magnitude was much too small (There is no need to show those results as the following arguments will show.). Of course one must remember that the dipole is a point model and can't account for different parts of the object mass being at different depths. Accordingly, the dipole strength was then varied iteratively until a peak response similar to that of the prolate spheroid was calculated. The result is shown in Figure 10 and is quite similar to that of the prolate spheroid results (Figure 9), except that the width at half-max is a little higher for the dipole. Note also that the dipole strength needed for this calculation was 1.1 amp-m<sup>2</sup>, resulting in a volume estimate that would have been 103 percent high for a target at a known depth. Therefore, an object at an odd angle caused the volume prediction to be high, instead of low as with an object normal to the earth's field. Similarly, assuming that the objects mass was known, the dipole model for the odd angle simulation would have predicted a depth that was too shallow, instead of too deep, as with the normal angle calculation. (It is interesting to note that the dipole contribution of the prolate spheroid simulation was calculated to be 0.97 amp-m<sup>2</sup>, once again not greatly different than what was required of the superimposed dipole model.)

Clearly, these simulations have shown that a simple dipole model has some utility in characterizing unmagnetized UXO orientations up to a 45 degree rotation; any rotation beyond that could not be predicted. Furthermore, it was demonstrated that the simple dipole underpredicted mass and overpredicted depth for an object normal to the earth's field, while overpredicting mass and underpredicting depth for an object at an odd angle to the earth's field. On the other hand, if projectiles possessed significant permanent, or remanant, magnetization that was known, results of dipole simulations might be more accurate and useful.

Max 56.4711 Min -5.9126

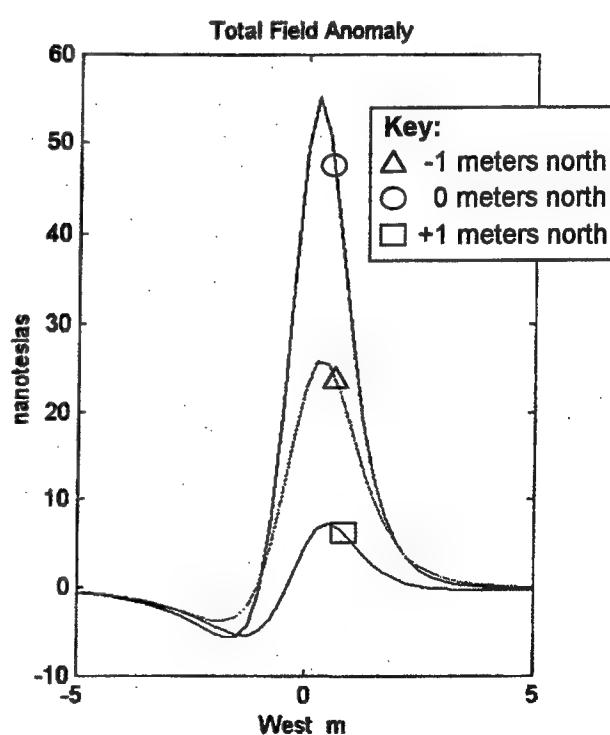
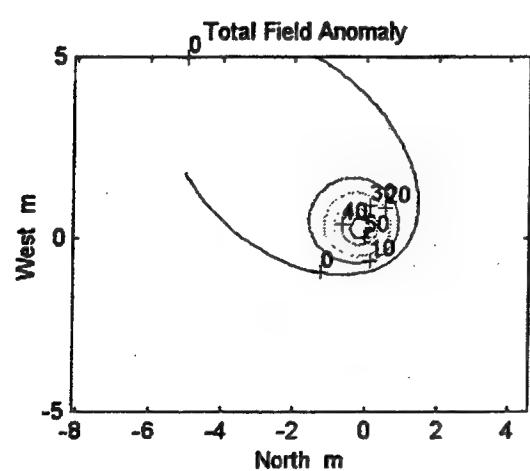
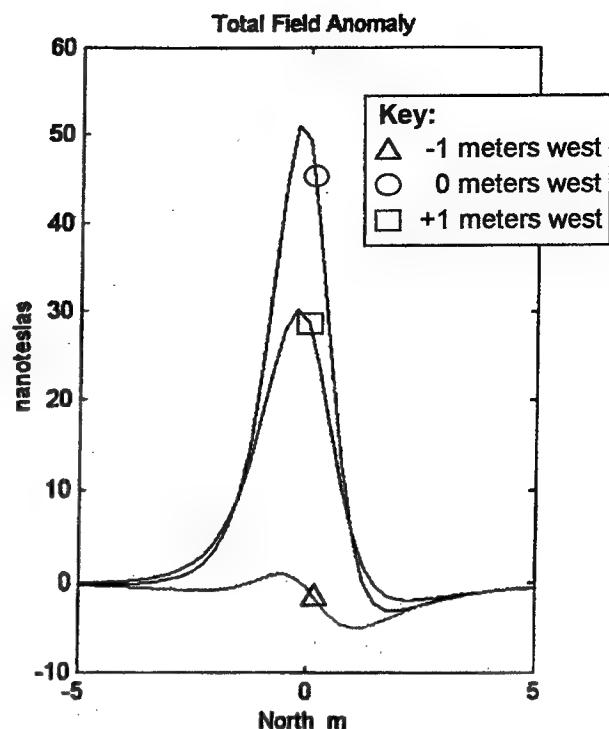
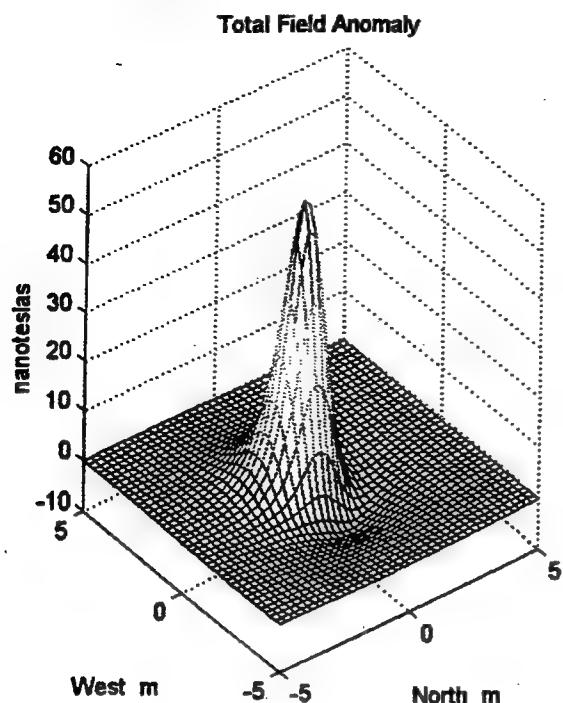


Figure 9. Prolate spheroid simulation of a 105 mm projectile (dip = 45 deg, az = 90 deg, depth = 1.43 m)

**total magnetic field less earth's field  
for a given magnetic dipole orientation**

earth's field (nT) = 57000

inclination of earth's field (degrees) 70

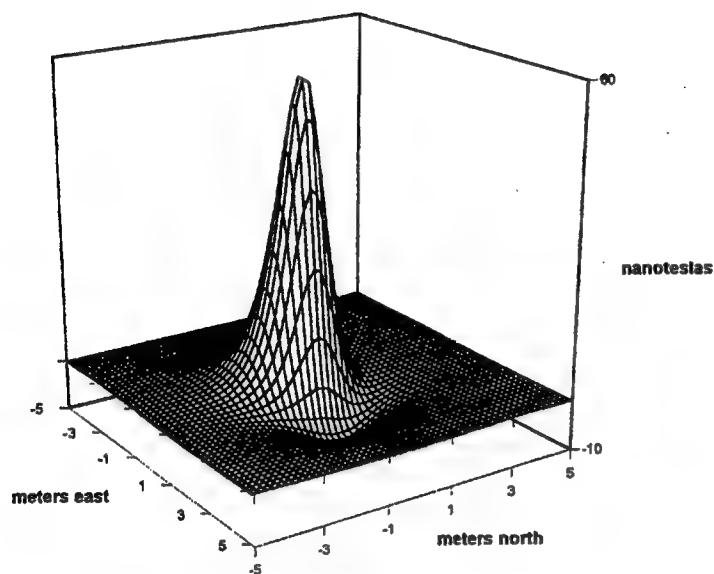
declination of earth's field (degrees) 0

dipole moment (amp-m<sup>2</sup>) = 1.1

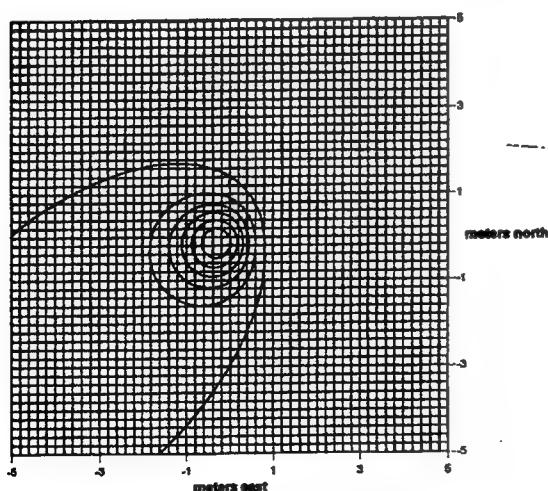
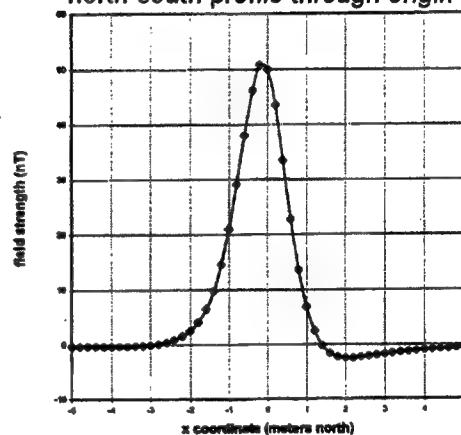
rotation angle of dipole from x-y plane (degrees) 45

rotation angle of dipole from positive x axis (degrees) 90

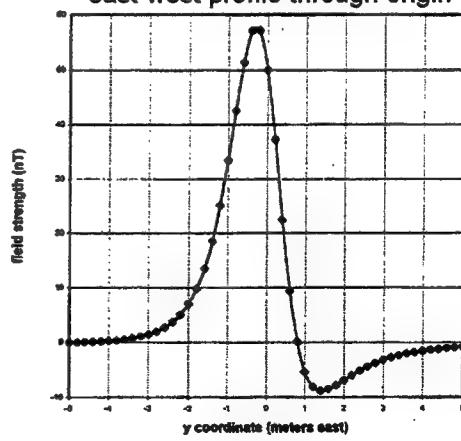
magnetometer elevation above point dipole = -1.43



**north-south profile through origin**



**east-west profile through origin**



**Figure 10.** Simple dipole simulation of a 105 mm projectile (dip = 45 deg, az = 90 deg, depth = 1.43 m)

## A known target in scenario 1

As noted earlier, ordnance item 1271, a 500 lb bomb, displayed a magnetic anomaly that could possibly be the result of a dipole moment induced by the earth's field at Jefferson Proving Ground. To complete this section on demonstrator detection and discrimination logic, both prolate spheroid and superimposed dipole simulations of item 1271 were conducted. The results of these simulations are contained in Figures 11 and 12. The earth's magnetic field was assigned a magnitude of 54297 nT, an inclination of 67.6 degrees, and a declination of -3.7 degrees, using a software product downloaded from the United States Geophysical Survey's National Geomagnetic Information Center, in Golden, CO (Quinn, et al 1995). Model input parameters were 38° north latitude, 85° west longitude, 400 foot elevation, and a test date of 10 October 1996. Total distance from the sensor to the object's center of mass was assumed to be 2.485 m (a magnetometer 0.65 m above the ground, the top of the bomb being 1.7 m below the surface, and the diameter of the bomb being 0.27 m).

**Prolate Spheroid Model.** Clearly, the prolate spheroid model does a good, but not excellent, job of simulating the measured total field magnetic anomaly of item 1271. The demonstrator data have a maximum response of about 177 nT (taken from the data disk provided by the contractor (GTL 1998)), while the model predicts a peak response of about 94 nT. The predicted axis orientation of the dipole-like response is about 41 degrees counterclockwise from north; whereas, the measured orientation was about 64 degrees.

**Simple Dipole Model.** Using the same logic as before for estimating the dipole moment strength of a 500 lb bomb, and given its maximum diameter to be 27 cm and its length to be 1.56 m, the dipole moment for item 1271 was estimated to be 11.578 amp-m<sup>2</sup>. The results of the simulation have the correct character, in the sense of response orientation, but the magnitude of the maximum response is about 56 nT, roughly a third of what was measured. As was argued previously, if the depth to the target was known from other measurements, this simulation would have resulted in an overprediction of target mass, or size.

Neither the prolate spheroid simulation, nor the simple superimposed dipole simulation did an excellent job of reproducing field data for this target. The higher-order model predicted a response closer to what was measured. The uncertainty associated with these simulations include actual sensor height, the true depth to the target (due to settling of the soil), and the true target orientation. Without having dug up the target on the day of the measurements to confirm its depth and orientation, these uncertainties will never be resolved.

One must also keep in mind that this object, as well as others located within the test sites, may possess some permanent magnetization. Therefore, any revisiting of JPG Phase III magnetic data also needs to be accompanied by measurements of the magnetization of each of the items to be reexamined.

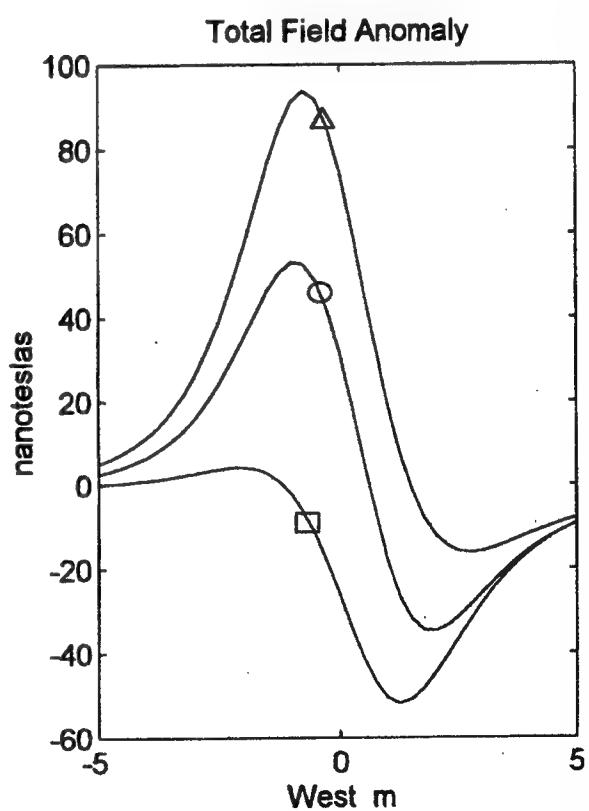
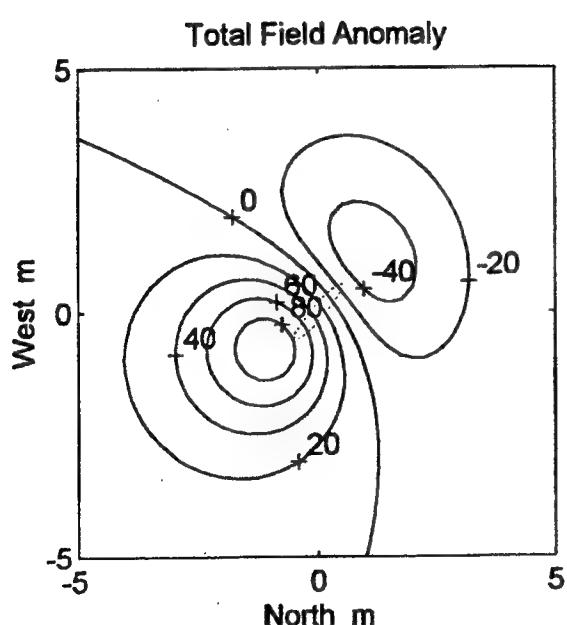
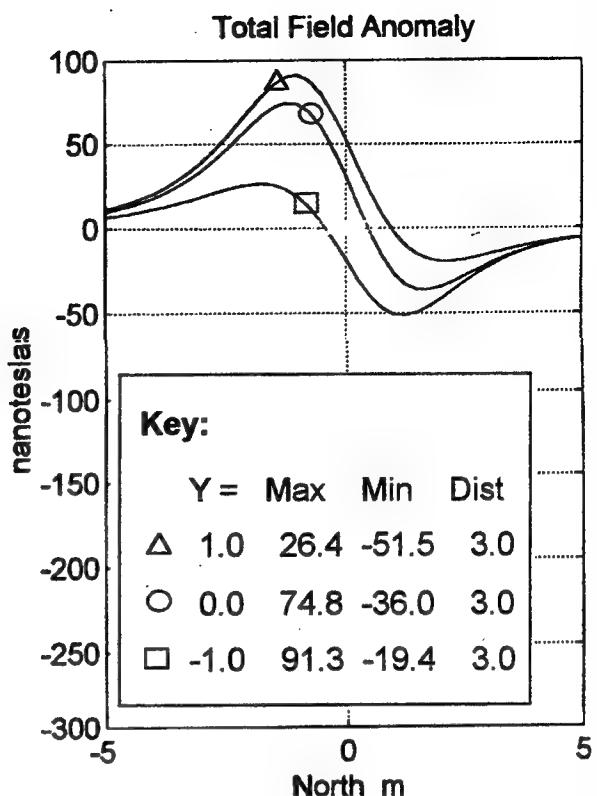
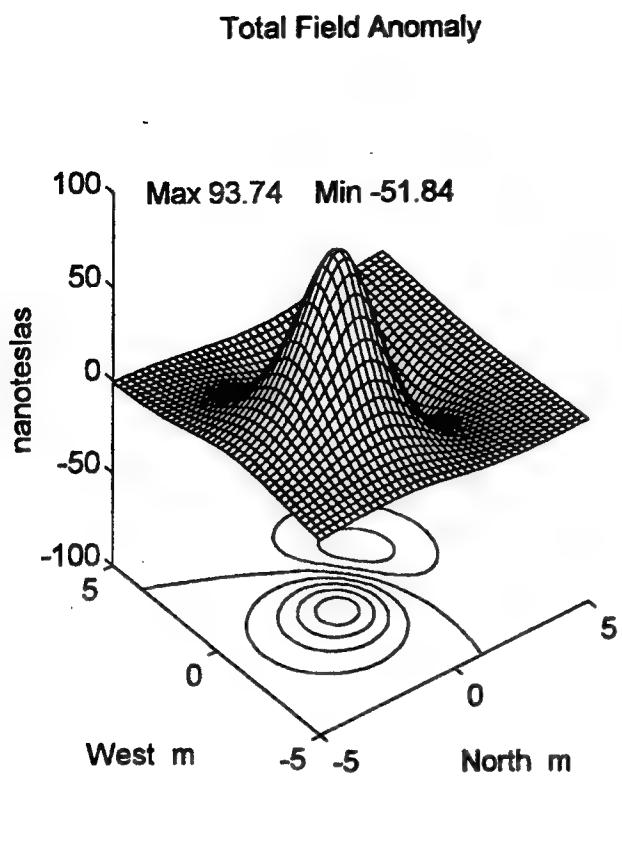


Figure 11. Prolate spheroid simulation of a 500 lb bomb (dip = 0 deg, az = -45 deg, depth = 2.49 m).

**total magnetic field less earth's field  
for a given magnetic dipole orientation**

earth's field (nT) = 54297

inclination of earth's field (degrees) 67.6

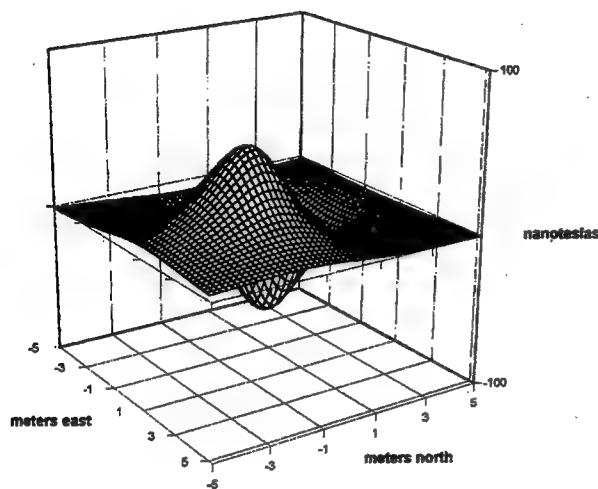
declination of earth's field (degrees) -3.7

dipole moment (amp-m<sup>2</sup>) = 11.578

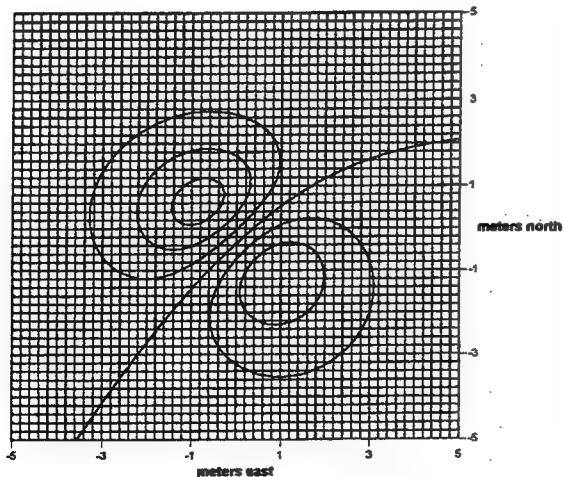
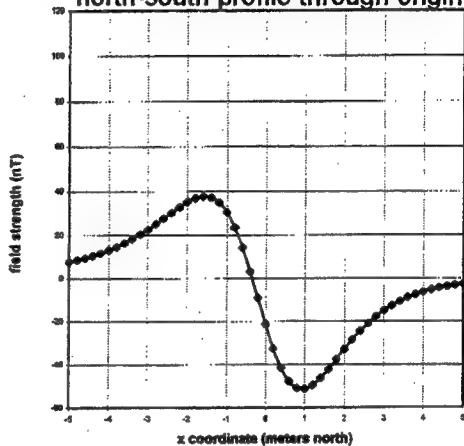
rotation angle of dipole from x-y plane (degrees) 0

rotation angle of dipole from positive x axis (degrees) -45

magnetometer elevation above point dipole = -2.485



**north-south profile through origin**



**east-west profile through origin**

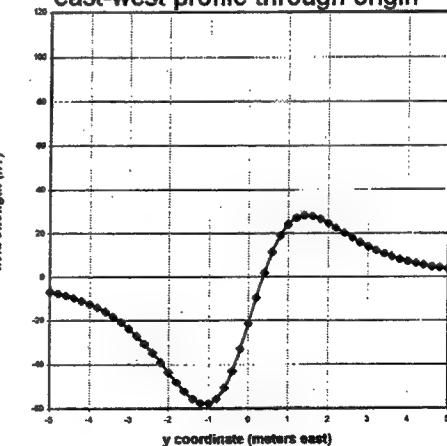


Figure 12. Simple dipole simulation of a 500 lb bomb (dip = 0 deg, az = -45 deg, depth = 2.49 m).

## **Contractor Rationalizations for Missed Targets**

Located in the appendices are copies of those portions of the contractor self-assessment reports that specifically addressed the reasons for having missed targets and lessons that some of the contractors felt they learned from this exercise. Too much detailed information is contained in those pages to warrant condensing them into a few phrases. Nevertheless, Table 6 does contain a very cursory summary of the general impressions of the contractor rationalizations gathered from their self-assessments.

What appears to be missing from these studies, and part of what was hoped for when the proposals were solicited, was detailed and honest discussion of whether or not data processing contributed significantly to contractor performance, whether or not they felt that their models were adequate for their data (GTL did specifically say that the magnetic dipole model was inadequate for target characterizations), or that their data were adequate for their models. There were suggestions that human errors contributed to some of the misses, but nothing was said about how the human factor could be minimized.

**Table 6  
Contractor Performance Rationalizations**

<b>ADI</b>	items were missed because they either had a low magnetic signature or there was interference from nearby geological anomalies; felt that the use of EMI in Scenarios 1 and 2 would have improved performance
<b>ENSCO</b>	needed multi-sensor approach to locate targets with low ferrous content; high false alarms due, in part, to low target selection threshold; would have benefited from better knowledge of geophysical responses of the targets buried at the sites; felt that ground penetrating radar usage would improve classification of UXO
<b>Geo-Centers</b>	target signatures below threshold; complex signatures from nearby anomalies; positional problems when negotiating obstacles
<b>GTL (formerly GRI)</b>	magnetometer sensor elevation needed to be lower and line spacing needed to be narrower; EMI interpretation threshold needed to be lower; data fusion algorithm was incorrect; magnetic dipole models inadequate for target characterizations; improvements in processing of EMI data would improve ability to distinguish UXO from non-UXO

## 3 Conclusions

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Clearly, demonstrator performance during Phase III of the JPG UXO Technology Demonstrations did not establish that technology has advanced to the point where site cleanup crews can cost-effectively detect and discriminate UXO on sites used for aerial bombing practice and land-based weapons training. It is also quite clear, from the contractor self-assessments of Phase III performance, that performance still heavily relies on human judgement and experience to separate potential UXO signatures from noise and to distinguish ordnance from non-ordnance items. Some modeling of target signatures has been done, but those models appear to be inadequate to perform either of these tasks.

While some of the questions posed in the Introduction were answered, many were not. For example, although there is universal agreement that multiple sensor technologies must be applied to this very complex problem, and most lean toward a combination of passive magnetic and electromagnetic induction sensors, there is still room for other innovative technologies.

In the area of modeling, comparison of magnetic dipole fields superimposed on the earth's field with measured data proved inadequate for accurately estimating target characteristics and were certainly not totally reliable in helping make ordnance vs non-ordnance decisions. There are at least two ways to approach this issue. One is that the model, itself, is not as sophisticated as it should be. The ERDC prolate spheroid model which combines induced dipole and octapole responses was shown to match, quite well, the total field signature of at one of the emplaced UXO at JPG. Revisiting the Phase III data with such a model would answer a number of questions. However, the magnetic data reported by one of the demonstrators that was discussed in some detail in an earlier section, make it very clear that many of the Phase III UXO signatures cannot be explained by magnetic moments induced by the earth's field. There are total field anomalies whose polarities are opposite of what any model would predict and others whose rotation in the horizontal plane can only be explained by permanent magnetization of the buried object. Permanent magnetization serves to further complicate the problem of classifying buried objects, and more study needs to be done to determine whether or not it is a problem for actual UXO.

The second approach to the concerns about models and data is to question whether or not the right kind of data have been collected. Most of the magnetic data collected at Phase III were of the total field variety. A very sensible question that begs for an answer is whether or not three-axis magnetic data coupled with realistic target models would reveal signatures that clearly distinguish ordnance from non-ordnance. Certainly, there is a chance that ferrous bodies of rotation immersed in the earth's magnetic field could produce anomalies that are different from shrapnel or other clutter objects. Careful study of three-axis magnetic data of real targets, surrogate targets, and debris could provide more powerful tools for classifying UXO.

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# **Appendix A: Demonstration Self Assessment Call for Proposals**

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# INFORMATION TO OFFERORS OR QUOTERS

Section A - Cover Sheet

1. SOLICITATION NUMBER	2. (X one)
DACA39-98-R-0009	a. SEALED BID
<input checked="" type="checkbox"/>	b. NEGOTIATED (RF)
	c. NEGOTIATED (RFP)

## INSTRUCTIONS

NOTE THE AFFIRMATIVE ACTION REQUIREMENT OF THE EQUAL OPPORTUNITY CLAUSE WHICH MAY APPLY TO THE CONTRACT RESULTING FROM THIS SOLICITATION.

You are cautioned to note the "Certification of Non-Segregated Facilities" in the solicitation. Failure to agree to the certification will render your reply nonresponsive to the terms of solicitations involving awards of contracts exceeding \$25,000 which are not exempt from the provisions of the Equal Opportunity clause.

"Fill-ins" are provided on the face and reverse of Standard Form 18 and Parts I and IV of Standard Form 33, or other solicitation documents and Sections of Table of Contents in this solicitation and should be examined for applicability.

See the provision of this solicitation entitled either "Late Bids, Modifications of Bids or Withdrawal of Bids" or "Late Proposals, Modifications of Proposals and Withdrawals of Proposals."

When submitting your reply, the envelope used must be plainly marked with the Solicitation Number, as shown above and the date and local time set forth for bid opening or receipt of proposals in the solicitation document.

If NO RESPONSE is to be submitted, detach this sheet from the solicitation, complete the information requested on reverse, fold, affix postage, and mail. NO ENVELOPE IS NECESSARY.

Replies must set forth full, accurate, and complete information as required by this solicitation (including attachments). The penalty for making false statements is prescribed in 18 U.S.C. 1001.

### 3. ISSUING OFFICE (Complete mailing address, including Zip Code)

**U.S. Army Engineer District, Vicksburg, CE**  
**4155 Clay Street**  
**Attn: CEMVK-CT-T**  
**Vicksburg, MS 39180-3435**

### ITEMS TO BE PURCHASED (Brief description)

JEFFERSON PROVING GROUNDS PHASE IV

### 5. PROCUREMENT INFORMATION (X and complete as applicable)

<input checked="" type="checkbox"/>	a. THIS PROCUREMENT IS UNRESTRICTED
	b. THIS PROCUREMENT IS A _____ % SET-ASIDE FOR ONE OF THE FOLLOWING (X one). (See Section C of the Table of Contents in this solicitation for details of the set-aside.)
	(1) Small Business      (2) Labor Surplus Area Concerns      (3) Combined Small Business/Labor Area Concerns

### 6. ADDITIONAL INFORMATION

### 7. POINT OF CONTACT FOR INFORMATION

NAME (Last, First, Middle Initial)

MICHAEL G. LEE

C18

b. ADDRESS (Include Zip Code)

**U.S. Army Engineer Dist., Vicksburg, CE**  
**4155 Clay St.**  
**Vicksburg, MS 39180-3435**

### c. TELEPHONE NUMBER (Include Area Code and Extension) (NOCOLLECT CALLS)

(601) 631-7254

OLICITATION, OFFER AND AWARD		1. THIS CONTRACT IS A RATED ORDER UNDER OPAS (15 CFR 700)	RATING C9E	PAGE OF PAGE 1   44
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SUBJECT	SUBJCTN#	4. TYPE OF SOLICITATION <input type="checkbox"/> SEALED BID (IFB) <input checked="" type="checkbox"/> NEGOTIATED (RFP)	5. DATE ISSUED 02/12/98	6. REQUISITION/PURCHASE NO. W81EWF-7317-4190
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SOLICITATION		7. ADDRESS OFFER TO (If other than Item 7) <b>U.S. Army Engineer District, Vicksburg, CE 4155 Clay St., CEMV-CT-T Vicksburg, MS 39180-3435</b>
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NOTE: In sealed bid solicitations "offer" and "offeror" mean "bid" and "bidder".

Sealed offers in original and in the depository located in	1 copies for furnishing the supplies or services in the Schedule will be received at the place specified in Item 8, or if handwritten, 4155 Clay St., Room 144 until 2:00 P.M. local time 03/10/98 (Hour) (Date)
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AUTION - LATE Submissions, Modifications, and Withdrawals. See Section L, Provision No. 52.214-7 or 52.215-10. All offers are subject to all terms and conditions contained in this solicitation.

9. FOR INFORMATION CALL:	A. NAME MICHAEL G. LEE	C18	B. TELEPHONE NO. (Include area code) (NO COLLECT CALLS) (601) 631-7254
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#### 11. TABLE OF CONTENTS

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X	B	SUPPLIES OR SERVICES AND PRICES/COSTS	1			PART III - LIST OF DOCUMENTS, EXHIBITS AND OTHER ATTACH.			
X	C	DESCRIPTION/SPECS./WORK STATEMENT	4		J	LIST OF ATTACHMENTS			
X	D	PACKAGING AND MARKING		<b>PART IV - REPRESENTATIONS AND INSTRUCTIONS</b>					
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X	H	SPECIAL CONTRACT REQUIREMENTS	2	X					

#### OFFER (Must be fully completed by offeror)

NOTE: Item 12 does not apply if the solicitation includes the provisions at 52.214-16, Minimum Bid Acceptance Period.

2. In compliance with the above, the undersigned agrees, if this offer is accepted within \_\_\_\_\_ calendar days (60 calendar days unless a different period is inserted by the offeror) from the date for receipt of offers specified above, to furnish any or all items upon which prices are offered at the price set opposite each item, delivered at the designated point(s), within the time specified in the schedule.

3. DISCOUNT FOR PROMPT PAYMENT (See Section I, Clause No. 52-232-8)	10 CALENDAR DAYS	20 CALENDAR DAYS	30 CALENDAR DAYS	CALENDAR
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4. ACKNOWLEDGEMENT OF AMENDMENTS (The offeror acknowledges receipt of amendments to the SOLICITATION for offerors and related documents numbered and dated:	AMENDMENT NO.	DATE	AMENDMENT NO.	DATE
--	---------------	------	---------------	------

5A. NAME AND ADDRESS OF OFFEROR	CAGE CODE	DUNS NUMBER	16. NAME AND TITLE OF PERSON AUTHORIZED TO SIGN OFFER (Type or print)
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5B. TELEPHONE NO. (Include area code)	15C. CHECK IF REMITTANCE ADDRESS IS DIFFERENT FROM ABOVE. ENTER SUCH ADDRESS IN SCHEDULE.	17. SIGNATURE	18. OFFER DA
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#### AWARD (To be completed by Government)

19. ACCEPTED AS TO ITEMS NUMBERED 0001	20. AMOUNT	21. ACCOUNTING AND APPROPRIATION 21720400000 088140 25C2004G03622784T4000 RK01
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22. AUTHORITY FOR USING OTHER THAN FULL AND OPEN COMPETITION: <input type="checkbox"/> 10 U.S.C. 2304(c) <input type="checkbox"/> 41 U.S.C. 253(c)	23. SUBMIT INVOICES TO ADDRESS SHOWN IN (4 copies unless otherwise specified)	ITEM Section B
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24. ADMINISTERED BY (If other than Item 7) CODE	25. PAYMENT WILL BE MADE BY DA, USACE, FINANCE CTR, 7800 3RD AVE, MILLINGTON, TN 38054-	CODE
--	--	------

26. NAME OF CONTRACTING OFFICER (Type or Print) JAMES A. BARR, Contract Specialist	27. UNITED STATES OF AMERICA (Signature of Contracting Officer)	28. AWARD DA
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IMPORTANT - Award will be made on this Form, or on Standard Form 26, or by other authorized official written notice.

NSN 7540-01-152-8064  
PREVIOUS EDITION NOT USABLE

SECTION B  
SUPPLIES OR SERVICES AND PRICES/COSTS

ITEM	DESCRIPTION	QUANTITY	U/I	UNIT PRICE	AMOUNT
0001	PERFORM A CRITICAL SELF-ASSESSMENT OF PERFORMANCE UNDER JEFFERSON PROVING GROUNDS PHASE III UXO DETECTION TECHNOLOGY DEMONSTRATIONS IN ACCORDANCE WITH SECTION C OF THIS PROPOSAL.	1.00	JB		
ESTIMATED COST \$					
FIXED FEE \$					

END OF SECTION B

SUBMIT INVOICES TO: USAE Waterways Experiment Station, CE  
3909 Halls Ferry Road  
Attn: CEWES-GV-B  
Vicksburg, MS 39180-6199

**Jefferson Proving Ground (JPG)  
UXO Technology Demonstration Program --  
Demonstrator Self-Assessments**

**U.S. Army Corps of Engineers, Waterways Experiment Station  
Vicksburg, Mississippi**

**Summary**

As part of an effort to bring a Science and Technology closure to the UXO Detection Technology Demonstrations (TD's) at JPG, the Government will consider proposals from JPG Phase III demonstrators to perform a critical self-assessment of their performance. The Government expects that the proposals will be relatively low cost, since no additional field work (data collection) or research and development is involved, i.e., the data already exists and the work will primarily involve documenting previous efforts.

This effort is summarized as follows:

- a. The government will fund a selected number of contractors to perform a self-assessment of their performance in JPG Phase III;
- b. The selected contractors will submit Part 1 of a technical report which documents the what, how, and why of their TD's along with the processed sensor data used for ordnance declarations;
- c. The government will provide the "ground truth" (locations and burial details of all inert ordnance and other objects buried at the sites) to the selected contractors for the self-assessment and for their subsequent use;
- d. The selected contractors will prepare and submit Part 2 of a technical report that provides a performance self-assessment.

**Proposals**

The proposals should include justification why the specific contractor should be funded to perform a self-assessment, i.e., what value will be added to the JPG experience after the specific self-assessment. The proposal should specify that all sensor data collected for the Phase III TD still exists and can be utilized for the self-assessment and provided to the government in the format specified below. The proposal should indicate how the data collection/field procedures, data processing, data integration, and ordnance versus non-ordnance decisions will be documented in the report. The proposal should indicate the extent to which maps, tables, flow charts, etc., will be used in the presentation.

## Ground Truth

Following receipt of the Part 1 of the technical report discussed above, the Government will deliver the relevant Phase III ground truth (baseline target set) to the selected contractors. The ground truth consists of location, depth, azimuth and inclination of all emplaced ordnance items. Also, the locations, depths and descriptions of all other emplaced objects will be provided. The ground truth information will be in the form of files on 3.5 in disks in a format which can be read by most spreadsheet and database programs, a tabular listing, and a map display.

## Self Assessments

Following receipt of the ground truth, the selected contractors will perform a critical self assessment of their TD performance and document in Part 2 of the technical report. The contractor sensor anomalies and resulting ordnance and non-ordnance declarations should be compared to the ground truth. Contractors should address the issue of all missed or non-declared ordnance: including (1) estimates of the extent to which sensor positioning/navigation errors or inaccuracies may have contributed to ordnance declaration misses, relative to the true ordnance location and the 2 m radius scoring criteria; and (2) consideration of possible effects of adjustable sensor thresholds, sensor sensitivity, sensor reliability, and graphical/plotting thresholds, range, and intervals on ordnance misses. The self assessment should include discussion of explanations and mitigating factors for the following, in addition to other factors of importance: anomalies that were apparently caused by ordnance which were classified as non-ordnance; anomalies that were apparently caused by non-ordnance which were classified as ordnance; anomalies that do not correlate with any emplaced object. *This critical self-assessment should not be viewed as an opportunity to provide or claim after-the-fact detections or inflated performance figures; the original ordnance-nonordnance detection declarations provided to the government stand alone as a demonstrator's best effort using the information and procedures available at the time of the TD.*

The proposal should include preliminary plans for the self assessment and a strategy for achieving an objective critique. Tentative plans for use of magnetic, electromagnetic induction, and/or ground penetrating radar modeling assessments, statistical comparisons, or other measures of performance or effectiveness should be indicated. The self assessment may indicate ways in which the TD planning and execution could have been improved or done differently by the Government, while maintaining an objective, unbiased, blind evaluation of technical capabilities. Such recommendations could include factors such as: more site specific geologic/geophysical information given to contractors in advance; less time and execution constraints on the TD; allowing pre-demonstration or advance access to the site (to view site conditions or for preliminary measurements); a different or modified "scoring" procedure; different definitions of false alarms; etc. The self assessment should include a roadmap of how the contractor's TD should/could have been performed better. That is, what were the key lessons learned from the JPG TD? Also, the self assessment can include a brief description of how the TD would be performed now, based on knowledge gained from or developments resulting from the TD. What new concepts, technology, or analysis methods are available now that weren't known or readily available during the TD?

SECTION E  
INSPECTION AND ACCEPTANCE

E.1 52.246-9

INSPECTION OF RESEARCH AND DEVELOPMENT (SHORT FORM) (APR 1984)  
(Reference 46.309)

END OF SECTION E

SECTION F  
DELIVERIES OR PERFORMANCE

F.1 PERIOD OF SERVICE

Period of Service.

All work under this contract shall be completed within twelve (12) months of the effective date of the contract.

END OF SECTION F

SECTION H  
SPECIAL CONTRACT REQUIREMENTS

H.1 TRAVEL COSTS

a. Travel in the United States required for performance of contract work will be made at the discretion of the Contractor. Travel outside the continental limits of the United States will not be performed without the prior approval of the Contracting Officer.

b. Travel to any scientific meeting or symposia for which the contractor expect reimbursement under this contract, shall not be undertaken without the prior approval of the Contracting Officer. Requests for such travel shall be submitted to the Contracting Officer six (6) weeks prior to meeting or symposia to allow for submission of request to higher headquarters four (4) weeks prior to date of meeting where local authority does not exist.

H.2 SOFTWARE RIGHTS

In accordance with DFARS 252.227-7013, "Rights in Technical Data and Computer Software," the Government shall be granted as a minimum the following restricted rights in any software delivered under this contract.

(a) Use of the computer software with the computer for which or with which it was acquired including use at any Government installation to which the computer may be transferred by the Government.

(b) Use of the computer software with a backup computer if the computer for which or with which it was acquired is inoperative;

(c) the right to copy computer programs for safekeeping (archives), backup purposes, and Continuity of Operations Plan;

(d) the right to modify computer software, or combine it with other software, subject to the provision that those portions of the derivative

SECTION I  
CONTRACT CLAUSES

I.1 52.252-2 CLAUSES INCORPORATED BY REFERENCE (JUN 1988)

This contract incorporates one or more clauses by reference, with the same force and effect as if they were given in full text. Upon request, the Contracting Officer will make their full text available.

(End of clause)

I.2 52.202-1

DEFINITIONS (OCT 1995)

(Reference 2.201)

I.3 52.203-3

GRATUITIES (APR 1984)

(Reference 3.202)

I.4 52.203-5

COVENANT AGAINST CONTINGENT FEES (APR 1984)

(Reference 3.404)

I.5 52.203-7

ANTI-KICKBACK PROCEDURES (JUL 1995)

(Reference 3.502-3)

I.6 52.203-10

PRICE OR FEE ADJUSTMENT FOR ILLEGAL OR IMPROPER ACTIVITY (JAN 1997)

(Reference 3.104-9(b))

I.7 52.203-12

LIMITATION ON PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS (JUN

1997)

(Reference 3.808(b))

I.8 52.204-2

SECURITY REQUIREMENTS (AUG 1996)

(Reference 4.404(a))

I.9 52.204-4

PRINTING/COPYING DOUBLE-SIDED ON RECYCLED PAPER (JUN 1996)

(Reference 4.304)

I.10 52.209-6

PROTECTING THE GOVERNMENT'S INTEREST WHEN SUBCONTRACTING WITH CONTRACTORS

DEBARRED, SUSPENDED, OR PROPOSED FOR DEBARMENT (JUL 1995)

(Reference 9.409(b))

I.11 52.211-15

DEFENSE PRIORITY AND ALLOCATION REQUIREMENTS (SEP 1990)

(Reference 11.604(b))

I.12 52.215-2

AUDIT AND RECORDS--NEGOTIATION (AUG 1996)

(Reference 15.209(b))

- I.26 52.227-2 NOTICE AND ASSISTANCE REGARDING PATENT AND COPYRIGHT INFRINGEMENT  
(AUG 1996)  
(Reference 27.202-2)
- I.27 52.227-12 PATENT RIGHTS--RETENTION BY THE CONTRACTOR (LONG FORM) (JAN 1997)  
(Reference 27.303(b)(1))
- I.28 52.228-7 INSURANCE--LIABILITY TO THIRD PERSONS (MAR 1996)  
(Reference 28.311-1)
- I.29 52.232-9 LIMITATION ON WITHHOLDING OF PAYMENTS (APR 1984)  
(Reference 32.111(c)(2))
- I.30 52.232-17 INTEREST (JUN 1996)  
(Reference 32.617(a)&())
- I.31 52.232-20 LIMITATION OF COST (APR 1984)  
(Reference 32.705-2(a))
- I.32 52.232-23 ASSIGNMENT OF CLAIMS (JAN 1986)  
(Reference 32.806(a)(1))
- I.33 52.232-25 PROMPT PAYMENT (JUN 1997)  
(Reference 32.908(c))
- I.34 52.233-1 DISPUTES (OCT 1995)  
(Reference 33.215)
- I.35 52.233-3 I PROTEST AFTER AWARD (AUG 1996)--ALTERNATE I (JUN 1985)  
(Reference 33.106(b))
- I.36 52.242-1 NOTICE OF INTENT TO DISALLOW COSTS (APR 1984)  
(Reference 42.802)
- I.37 52.242-13 BANKRUPTCY (JUL 1995)  
(Reference 42.903)
- I.38 52.242-15 I STOP-WORK ORDER (AUG 1989)--ALTERNATE I (APR 1984)  
(Reference 42.1305(b))

I.52 252.227-7030 TECHNICAL DATA--WITHHOLDING OF PAYMENT (OCT 1988)  
(Reference 27.7103-6(f))

I.53 252.227-7036 DECLARATION OF TECHNICAL DATA CONFORMITY (JAN 1997)  
(Reference 27.7103-6(e))

I.54 252.227-7037 VALIDATION OF RESTRICTIVE MARKINGS ON TECHNICAL DATA (NOV 1995)  
(Reference 27.7102-3(c))

I.55 252.231-7000 SUPPLEMENTAL COST PRINCIPLES (DEC 1991)  
(Reference 31.100-70)

I.56 52.245-5 GOVERNMENT PROPERTY (COST-REIMBURSEMENT, TIME-AND-MATERIAL, OR  
LABOR-HOUR CONTRACTS) (JAN 1986)

(a) Government-furnished property.

(1) The term "Contractor's managerial personnel," as used in paragraph (g) of this clause, means any of the Contractor's directors, officers, managers, superintendents, or equivalent representatives who have supervision or direction of--

(i) All or substantially all of the Contractor's business;

(ii) All or substantially all of the Contractor's operation at any one plant, or separate location at which the contract is being performed; or

(iii) A separate and complete major industrial operation connected with performing this contract.

(2) The Government shall deliver to the Contractor, for use in connection with and under the terms of this contract, the Government-furnished property described in the Schedule or specifications, together with such related data and information as the Contractor may request and as may be reasonably required for the intended use of the property (hereinafter referred to as "Government-furnished property").

(3) The delivery or performance dates for this contract are based upon the expectation that Government-furnished property suitable for use will be delivered to the Contractor at the times stated in the Schedule or, if not so stated, in sufficient time to enable the Contractor to meet the contract's delivery or performance dates.

(4) If Government-furnished property is received by the Contractor in a condition not suitable for the intended use, the Contractor shall, upon receipt, notify the Contracting Officer, detailing the facts, and, as

the Contractor, title to which vests in the Government under this paragraph (collectively referred to as "Government property"), are subject to the provisions of this clause. Title to Government property shall not be affected by its incorporation into or attachment to any property not owned by the Government, nor shall Government property become a fixture or lose its identity as personal property by being attached to any real property.

(d) Use of Government property. The Government property shall be used only for performing this contract, unless otherwise provided in this contract or approved by the Contracting Officer.

(e) Property administration. (1) The Contractor shall be responsible and accountable for all Government property provided under the contract and shall comply with Federal Acquisition Regulation (FAR) Subpart 45.5, as in effect on the date of this contract.

(2) The Contractor shall establish and maintain a program for the use, maintenance, repair, protection, and preservation of Government property in accordance with sound business practice and the applicable provisions of FAR Subpart 45.5.

(3) If damage occurs to Government property, the risk of which has been assumed by the Government under this contract, the Government shall replace the items or the Contractor shall make such repairs as the Government directs. However, if the Contractor cannot effect such repairs within the time required, the Contractor shall dispose of the property as directed by the Contracting Officer. When any property for which the Government is responsible is replaced or repaired, the Contracting Officer shall make an equitable adjustment in accordance with paragraph (h) of this clause.

(f) Access. The Government and all its designees shall have access at all reasonable times to the premises in which any Government property is located for the purpose of inspecting the Government property.

(g) Limited risk of loss. (1) The Contractor shall not be liable for loss or destruction of, or damage to, the Government property provided under this contract or for expenses incidental to such loss, destruction, or damage, except as provided in subparagraphs (2) and (3) below.

(2) The Contractor shall be responsible for loss or destruction of, or damage to, the Government property provided under this contract (including expenses incidental to such loss, destruction, or damage)--

(i) That results from a risk expressly required to be insured under this contract, but only to the extent of the insurance required to be purchased and maintained or to the extent of insurance actually purchased and maintained, whichever is greater;

(5) Upon loss or destruction of, or damage to, Government property provided under this contract, the Contractor shall so notify the Contracting Officer and shall communicate with the loss and salvage organization, if any, designated by the Contracting Officer. With the assistance of any such organization, the Contractor shall take all reasonable action to protect the Government property from further damage, separate the damaged and undamaged Government property, put all the affected Government property in the best possible order, and furnish to the Contracting Officer a statement of--

- (i) The lost, destroyed, or damaged Government property;
- (ii) The time and origin of the loss, destruction, or damage;
- (iii) All known interests in commingled property of which the Government property is a part; and
- (iv) The insurance, if any, covering any part of or interest in such commingled property.

(6) The Contractor shall repair, renovate, and take such other action with respect to damaged Government property as the Contracting Officer directs. If the Government property is destroyed or damaged beyond practical repair, or is damaged and so commingled or combined with property of others (including the Contractor's) that separation is impractical, the Contractor may, with the approval of and subject to any conditions imposed by the Contracting Officer, sell such property for the account of the Government. Such sales may be made in order to minimize the loss to the Government, to permit the resumption of business, or to accomplish a similar purpose. The Contractor shall be entitled to an equitable adjustment in the contract price for the expenditures made in performing the obligations under this subparagraph (g)(6) in accordance with paragraph (h) of this clause. However, the Government may directly reimburse the loss and salvage organization for any of their charges. The Contracting Officer shall give due regard to the Contractor's liability under this paragraph (g) when making any such equitable adjustment.

(7) The Contractor shall not be reimbursed for, and shall not include as an item of overhead, the cost of insurance or of any reserve covering risk of loss or destruction of, or damage to, Government property, except to the extent that the Government may have expressly required the Contractor to carry such insurance under another provision of this contract.

(8) In the event the Contractor is reimbursed or otherwise compensated for any loss or destruction of, or damage to, Government property, the Contractor shall use the proceeds to repair, renovate, or replace the

chips, cuttings, borings, turnings, short ends, circles, trimmings, clippings, and remnants, and to dispose of such scrap in accordance with the Contractor's normal practice and account for it as a part of general overhead or other reimbursable costs in accordance with the Contractor's established accounting procedures.

(j) Abandonment and restoration of Contractor premises. Unless otherwise provided herein, the Government--

(1) May abandon any Government property in place, at which time all obligations of the Government regarding such abandoned property shall cease; and

(2) Has no obligation to restore or rehabilitate the Contractor's premises under any circumstances (e.g., abandonment, disposition upon completion of need, or contract completion). However, if the Government-furnished property (listed in the Schedule or specifications) is withdrawn or is unsuitable for the intended use, or if other Government property is substituted, then the equitable adjustment under paragraph (h) of this clause may properly include restoration or rehabilitation costs.

(k) Communications. All communications under this clause shall be in writing.

(l) Overseas contracts. If this contract is to be performed outside the United States of America, its territories, or possessions, the words "Government" and "Government-furnished" (wherever they appear in this clause) shall be construed as "United States Government" and "United States Government-furnished," respectively.

(End of clause)

END OF SECTION I

SECTION K  
REPRESENTATIONS, CERTIFICATIONS AND OTHER STATEMENTS OF OFFERORS

K.1 52.203-8

CANCELLATION, RESCISSION, AND RECOVERY OF FUNDS FOR ILLEGAL OR IMPROPER ACTIVITY (JAN 1997)

(a) If the Government receives information that a contractor or a person has engaged in conduct constituting a violation of subsection (a), (b), (c), or (d) of Section 27 of the Office of Federal Procurement Policy Act (41 U.S.C. 423) (the Act), as amended by section 4304 of the National Defense Authorization Act for Fiscal Year 1996 (Pub. L. 104-106), the Government may:

- (1) Cancel the solicitation, if the contract has not yet been awarded or issued; or
- (2) Rescind the contract with respect to which:
  - (i) The Contractor or someone acting for the Contractor has been convicted for an offense where the conduct constitutes a violation of subsection 27 (a) or (b) of the Act for the purpose of either--
    - (A) Exchanging the information covered by such subsections for anything of value; or
    - (B) Obtaining or giving anyone a competitive advantage in the award of a Federal agency procurement contract; or
  - (ii) The head of the contracting activity has determined, based upon a preponderance of the evidence, that the Contractor or someone acting for the Contractor has engaged in conduct constituting an offense punishable under subsection 27(e)(1) of the Act.
- (b) If the Government rescinds the contract under paragraph (a) of this clause, the Government is entitled to recover, in addition to any penalty prescribed by law, the amount expended under the contract.
- (c) The rights and remedies of the Government specified herein are not exclusive, and are in addition to any other rights and remedies provided by law, regulation, or under this contract.

(End of clause)

K.2 52.203-11

CERTIFICATION AND DISCLOSURE REGARDING PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS (APR 1991)

(a) The definitions and prohibitions contained in the clause, at FAR 52.203-12, Limitation on Payments to Influence Certain Federal Transactions, included in this solicitation, are hereby incorporated by reference in paragraph (b) of this certification.

(b) The offeror, by signing its offer, hereby certifies to the best of

designation as to whether the offeror is a corporate entity, an unincorporated entity (e.g., sole proprietorship or partnership), or a corporation providing medical and health care services.

"Taxpayer Identification Number (TIN)," as used in this solicitation provision, means the number required by the IRS to be used by the offeror in reporting income tax and other returns.

(b) All offerors are required to submit the information required in paragraphs (c) through (e) of this solicitation provision in order to comply with reporting requirements of 26 U.S.C. 6041, 6041A, and 6050M and implementing regulations issued by the Internal Revenue Service (IRS). If the resulting contract is subject to the reporting requirements described in FAR 4.903, the failure or refusal by the offeror to furnish the information may result in a 31 percent reduction of payments otherwise due under the contract.

(c) Taxpayer Identification Number (TIN).

TIN: \_\_\_\_\_

TIN has been applied for.

TIN is not required because:

Offeror is a nonresident alien, foreign corporation, or foreign partnership that does not have income effectively connected with the conduct of a trade or business in the U.S. and does not have an office or place of business or a fiscal paying agent in the U.S.;

Offeror is an agency or instrumentality of a foreign government;

Offeror is an agency or instrumentality of a Federal, state, or local government;

Other. State basis. \_\_\_\_\_

(d) Corporate Status.

Corporation providing medical and health care services, or engaged in the billing and collecting of payments for such services;

Other corporate entity;

Not a corporate entity;

Sole proprietorship

Partnership

Hospital or extended care facility described in 26 CFR 501(c)(3) that is exempt from taxation under 26 CFR 501(a).

(e) Common Parent.

Offeror is not owned or controlled by a common parent as defined in paragraph (a) of this provision.

Name and TIN of common parent:

Name \_\_\_\_\_

TIN \_\_\_\_\_

by reason of changed circumstances.

(c) A certification that any of the items in paragraph (a) of this provision exists will not necessarily result in withholding of an award under this solicitation. However, the certification will be considered in connection with a determination of the Offeror's responsibility. Failure of the Offeror to furnish a certification or provide such additional information as requested by the Contracting Officer may render the Offeror nonresponsible.

(d) Nothing contained in the foregoing shall be construed to require establishment of a system of records in order to render, in good faith, the certification required by paragraph (a) of this provision. The knowledge and information of an Offeror is not required to exceed that which is normally possessed by a prudent person in the ordinary course of business dealings.

(e) The certification in paragraph (a) of this provision is a material representation of fact upon which reliance was placed when making award. If it is later determined that the Offeror knowingly rendered an erroneous certification, in addition to other remedies available to the Government, the Contracting Officer may terminate the contract resulting from this solicitation for default.

(End of provision)

K.5 52.215-6

PLACE OF PERFORMANCE (OCT 1997)

(a) The offeror or respondent, in the performance of any contract resulting from this solicitation, [ ] intends, [ ] does not intend (check applicable block) to use one or more plants or facilities located at a different address from the address of the offeror or respondent as indicated in this proposal or response to request for information.

(b) If the offeror or respondent checks "intends" in paragraph (a) of this provision, it shall insert in the following spaces the required information:

-----  
Place of performance (street \_\_\_\_\_ Name and address of owner and  
address, city, state, county, zip \_\_\_\_\_ operator of the plant or facility  
code) \_\_\_\_\_ if other than offeror or respondent  
-----

dominant in the field of operation in which it is bidding on Government contracts, and qualified as a small business under the criteria in 13 CFR Part 121 and the size standard in paragraph (a) of this provision.

"Small disadvantaged business concern," as used in this provision, means a small business concern that (1) is at least 51 percent unconditionally owned by one or more individuals who are both socially and economically disadvantaged, or a publicly owned business having at least 51 percent of its stock unconditionally owned by one or more socially and economically disadvantaged individuals, and (2) has its management and daily business controlled by one or more such individuals. This term also means a small business concern that is at least 51 percent unconditionally owned by an economically disadvantaged Indian tribe or Native Hawaiian Organization, or a publicly owned business having at least 51 percent of its stock unconditionally owned by one or more of these entities, which has its management and daily business controlled by members of an economically disadvantaged Indian tribe or Native Hawaiian Organization, and which meets the requirements of 13 CFR Part 124.

"Women-owned small business concern," as used in this provision, means a small business concern--

(1) Which is at least 51 percent owned by one or more women or, in the case of any publicly owned business, at least 51 percent of the stock of which is owned by one or more women; and

(2) Whose management and daily business operations are controlled by one or more women.

(d) Notice. (1) If this solicitation is for supplies and has been set aside, in whole or in part, for small business concerns, then the clause in this solicitation providing notice of the set-aside contains restrictions on the source of the end items to be furnished.

(2) Under 15 U.S.C. 645(d), any person who misrepresents a firm's status as a small or small disadvantaged business concern in order to obtain a contract to be awarded under the preference programs established pursuant to sections 8(a), 8(d), 9, or 15 of the Small Business Act or any other provision of Federal law that specifically references section 8(d) for a definition of program eligibility, shall--

(i) Be punished by imposition of fine, imprisonment, or both;

(ii) Be subject to administrative remedies, including suspension and debarment; and

(iii) Be ineligible for participation in programs conducted under the authority of the Act.

(End of provision)

(R 1-12.803-10(d))

K.8 52.222-22 PREVIOUS CONTRACTS AND COMPLIANCE REPORTS (APR 1984)

The offeror represents that--

- (a) It / / has, / / has not, participated in a previous contract or subcontract subject either to the Equal Opportunity clause of this solicitation, the clause originally contained in Section 310 of Executive Order No. 10925, or the clause contained in Section 201 of Executive Order No. 11114;
- (b) It / / has, / / has not, filed all required compliance reports; and
- (c) Representations indicating submission of required compliance reports, signed by proposed subcontractors, will be obtained before subcontract awards.

(End of provision)

(R 7-2003.14(b)(1)(B) 1973 APR)

K.9 52.222-25 AFFIRMATIVE ACTION COMPLIANCE (APR 1984)

The offeror represents that (a) it / / has developed and has on file, / / has not developed and does not have on file, at each establishment, affirmative action programs required by the rules and regulations of the Secretary of Labor (41 CFR 60-1 and 60-2), or (b) it / / has not previously had contracts subject to the written affirmative action programs requirement of the rules and regulations of the Secretary of Labor.

(End of provision)

(R 7-2003.14(b) 1979 SEP)

(R 1-12.805-4)

K.10 252.209-7000 ACQUISITION FROM SUBCONTRACTORS SUBJECT TO ON-SITE INSPECTION UNDER THE  
INTERMEDIATE-RANGE NUCLEAR FORCES (INF) TREATY (NOV 1995)

- (a) The Contractor shall not deny consideration for a subcontract award under this contract to a potential subcontractor subject to on-site inspection under the INF Treaty, or a similar treaty, solely or in part

Black American (U.S. citizen)  
 Hispanic American (U.S. citizen with origins from South America, Central America, Mexico, Cuba, the Dominican Republic, Puerto Rico, Spain, or Portugal)  
 Native American (American Indians, Eskimos, Aleuts, or Native Hawaiians, including Indian tribes or Native Hawaiian organizations)  
 Individual/concern, other than one of the preceding, currently certified for participation in the Minority Small Business and Capital Ownership Development Program under Section 8(a) of the Small Business Act

Other

(c) Complete the following--

(1) The offeror is \_\_\_\_\_ is not \_\_\_\_\_ a small disadvantaged business concern.

(2) The Small Business Administration (SBA) has \_\_\_\_\_ has not \_\_\_\_\_ made a determination concerning the offeror's status as a small disadvantaged business concern. If the SBA has made a determination, the date of the determination was \_\_\_\_\_ and the offeror--

Was found by SBA to be socially and economically disadvantaged and no circumstances have changed to vary that determination.

Was found by SBA not to be socially and economically disadvantaged but circumstances which caused the determination have changed.

(d) Penalties and Remedies. Anyone who misrepresents the status of a concern as a small disadvantaged business for the purpose of securing a contract or subcontract shall--

(1) Be punished by imposition of a fine, imprisonment, or both;

(2) Be subject to administrative remedies, including suspension and debarment; and

(3) Be ineligible for participation in programs conducted under authority of the Small Business Act.

(End of provision)

K.12 252.225-7000 BUY AMERICAN ACT--BALANCE OF PAYMENTS PROGRAM CERTIFICATE (DEC 1991)

(a) Definitions. "Domestic end product," "qualifying country," "qualifying country end product," and "nonqualifying country end product" have the meanings given in the Buy American Act and Balance of Payments Program clause of this solicitation.

(b) Evaluation. Offers will be evaluated by giving preference to

I \_\_\_\_\_, certify that I am secretary of the organization named as contractor herein; that \_\_\_\_\_ who signed this contract on behalf of the contractor, was then \_\_\_\_\_ of said organization; that said contract was duly signed for and on behalf of said organization by authority of its governing body and is within the scope of its power.

\_\_\_\_\_  
SECRETARY

K.14

CERTIFICATE OF INDIRECT COSTS

In accordance with the contract clause entitled "Certification of Indirect Cost," DFARS 52.242-7003, the offeror is required to complete the following:

CERTIFICATE OF INDIRECT COSTS (APR 1986)

This is to certify to the best of my knowledge and belief:

1. I have reviewed the indirect cost proposal submitted herewith;

2. All costs included in this proposal \_\_\_\_\_

(identify)

to establish billing or final indirect costs

(date)

rates for \_\_\_\_\_

(identify period covered by rate)

are allowable in accordance with the requirements of contracts to which they apply and with the cost principles of the Department of Defense applicable to those contracts;

3. This proposal does not include any costs which are unallowable under applicable cost principles of the Department of Defense, such as (without limitations): advertising and public relations costs, contributions and donations, entertainment costs, fines and penalties, lobbying costs, defense of fraud proceedings, and good will; and

SECTION L  
INSTRS., CONDS., AND NOTICES TO OFFERORS

L.1

52.252-1

SOLICITATION PROVISIONS INCORPORATED BY REFERENCE (JUN 1988)

This solicitation incorporates one or more solicitation provisions by reference, with the same force and effect as if they were given in full text. Upon request, the Contracting Officer will make their full text available.

(End of provision)

L.2

52.204-6

CONTRACTOR IDENTIFICATION NUMBER--DATA UNIVERSAL NUMBERING SYSTEM (DUNS)  
NUMBER (DEC 1996)

(a) Contractor Identification Number, as used in this provision, means "Data Universal Numbering System (DUNS) number," which is a nine-digit number assigned by Dun and Bradstreet Information Services.

(b) Contractor identification is essential for complying with statutory contract reporting requirements. Therefore, the offeror is requested to enter, in the block with its name and address on the Standard Form 33 or similar document, the annotation "DUNS" followed by the DUNS number which identifies the offeror's name and address exactly as stated in the offer.

(c) If the offeror does not have a DUNS number, it should contact Dun and Bradstreet directly to obtain one. A DUNS number will be provided immediately by telephone at no charge to the offeror. For information on obtaining a DUNS number, the offeror should call Dun and Bradstreet at 1-800-333-0505. The offeror should be prepared to provide the following information:

- (1) Company name.
- (2) Company address.
- (3) Company telephone number.
- (4) Line of business.
- (5) Chief executive officer/key manager.
- (6) Date the company was started.
- (7) Number of people employed by the company.
- (8) Company affiliation.

(d) Offerors located outside the United States may obtain the location and phone number of the local Dun and Bradstreet Information Services office from the Internet Home Page at <http://www.dbisna.com/dbis/customer/custlist.htm>. If an offeror is unable to locate a local service center, it may send an e-mail to Dun and Bradstreet at [globalinfo@dbisma.com](mailto:globalinfo@dbisma.com).

(End of provision)

requires submission of cost or pricing data not otherwise required by law or regulation.

(b) When requested by the Contracting Officer, the Offeror/Contractor shall also identify those supplies that it will not manufacture or to which it will not contribute significant value.

(c) The Contractor shall insert the substance of this clause, less paragraph (b), in all subcontracts for other than: acquisitions at or below the simplified acquisition threshold in FAR Part 2; construction or architect-engineer services under FAR Part 36; utility services under FAR Part 41; services where supplies are not required; commercial items; and petroleum products.

(End of clause)

L.6 52.216-1

TYPE OF CONTRACT (APR 1984)

The Government contemplates award of a cost-plus-fixed-fee contract resulting from this solicitation.

(End of provision)

L.7

CONTRACT CLAUSE AND SOLICITATION PROVISION NUMBERING SYSTEM

This document is computer-generated by the Standard Army Automated Contracting System (SAACONS). The numbering system used by the computer for contract clauses and solicitation provisions differs slightly from the procurement regulations but is similar and easily recognizable. The Federal Acquisition Regulation (FAR) uses a numbering system for contract clause and solicitation provisions as follows:

52.2xx-1 and higher (e.g., 52.215-5)

SAACONS uses a 10-digit number in the format of 52.02xx-xxxx. The SAACONS number for the same clause would be 52.215-0005. FAR contract clauses and solicitation provisions are recognized by a "0" in the 7th digit of the SAACONS number. Department of Defense Federal Acquisition

sticker with blanks provided for the information required by the clause in this section entitled "MARKING OF PROPOSALS." Hand carried proposals must be delivered to the Contract Branch, Contracting Division, Building 3072, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS, prior to the time for closing.

(Competitive Proposals Only)

L.10

#### SMALL BUSINESS CONCERNs

The supplies or services to be procured under this solicitation are classified in the Standard Industrial Classification as Code 8731. For the purpose of this procurement to qualify as a small business concern, in addition to being independently owned and operated and not dominant in the field of operation in which it is bidding on Government contracts, the average annual number of employees of the concern and its affiliates for the preceding three (3) fiscal years must not exceed 500.

NOTE: THIS IS (      ) IS NOT (XX) 100% SET-ASIDE FOR SMALL BUSINESS.

END OF SECTION L

SECTION M  
EVALUATION FACTORS FOR AWARD

1. EVALUATION CRITERIA

a. Price Related Factors.

THE COMBINED TECHNICAL FACTORS ARE SIGNIFICANTLY MORE IMPORTANT THAN PRICE

COST IS NOT EXPECTED TO BE THE CONTROLLING FACTOR IN THE SELECTION OF A CONTRACTOR FOR THIS SOLICITATION. THE DEGREE OF IMPORTANCE OF COST AS A FACTOR COULD BECOME GREATER DEPENDING UPON THE EQUALITY OF THE PROPOSALS FOR OTHER FACTORS EVALUATED. WHERE COMPETING PROPOSALS ARE DETERMINED TO BE SUBSTANTIALLY EQUAL, TOTAL COST AND OTHER COST FACTORS COULD BECOME THE CONTROLLING FACTOR.

Award will be made to that responsive and responsible offeror whose proposal is determined to be most advantageous to the Government, cost and other criteria considered. Although overall cost to the Government will be seriously considered, technical approach and capability are of paramount importance. The contract could, therefore, be awarded to other than the low final offeror, if it is determined to represent the greatest value to the Government; however, the total cost is significant in that the Government may not be capable of awarding a contract simply because the proposal cannot be afforded.

b. Technical Factors.

- (1) Approach to critical self-assessment. The proposed approach to accomplishing a critical self-assessment of demonstration performance as documented in the proposal - sound methodology, thoroughness, novel techniques, expressed non-promotional intent, procedure for documenting results. This factor is more important than technical factor (2) and significantly more important than technical factor (3).
- (2) Past performance and experience. Past experience in critical performance documentation and UXO research, development and technology demonstration, e.g., participation in Jefferson Proving Ground Phases I and II or other technology demonstrations, peer-reviewed publications, proceedings papers, etc. This factor is more important than technical factor (3).

3. Offerors are reminded that assertions of compliance with the solicitation which are not supported are insufficient. Proposals must not merely reflect the contractual objectives but must also provide convincing documentation in support of promised performance.

4. The burden of proof as to cost realism rests with the offeror. The proposal of the offeror is presumed to represent the best efforts to respond to the solicitation. Any inconsistency, whether real or apparent, between promised performance and proposed cost shall be explained in the proposal. Unexplained inconsistencies resulting from the offeror's lack of understanding of the nature and scope of work required, or their lack of financial ability, to perform the contract, may be grounds for rejection of the proposal.

END OF SECTION M

## **Appendix B: A Portion of the ADI, Limited Self Assessment Report**

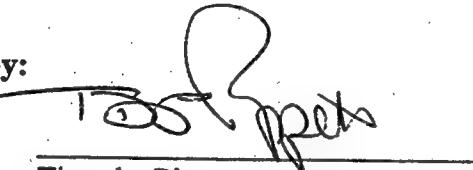
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**TECHNICAL REPORT No: 2  
JEFFERSON PROVING GROUND (JPG)  
UXO TECHNOLOGY DEMONSTRATION PROGRAM  
DATA SELF-ASSESSMENT**

**For:** US Army Corps of Engineers  
Waterways Experiment Station  
Vicksburg. Mississippi. USA.

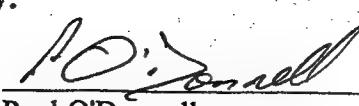
**By:** ADI Limited - Major Projects Group  
100 William Street  
East Sydney. NSW. Australia.

**Prepared by:**

  
\_\_\_\_\_  
Timothy Pippett  
Consulting Geophysicist  
(Alpha Geoscience Pty. Limited)

**Date:** 01 October 98

**Authorised by:**

  
\_\_\_\_\_  
Paul O'Donnell  
Principal Geophysicist  
Project Manager

**Date:** 01 October 98

### **3. ASSESSMENT OF RESULTS**

#### **3.1 ADI's Data Analysis**

The color images in Appendix 2 are a compilation of the control item positions, the original ADI interpretations and the Geosoft UXO interpretations overlaying the analytic signal grid calculated by the Geosoft package. The result of the data analysis on the ADI interpretations is included in Appendix 4 of this report.

The analysis of the ADI results is broken down into the four scenarios.

##### **3.1.1 Scenario 1**

The eight 2.75" rocket motors and one 5" rocket motor that was missed in the interpretation generally did not have a magnetic signature or if they did it was close to the magnetic noise envelope.

No other ordnance items were missed in the initial interpretation, all other items that were missed were of a non-ordnance nature.

##### **3.1.2 Scenario 2**

The following ordnance items were missed in this Scenario:

60-mm Mortars	missed 6 of 12 total	(50%)
105-mm Projectiles	missed 3 of 17 total	(82%)
81-mm Mortars	missed 1 of 17 total	(94%)

No other ordnance items were missed in the initial interpretation, all other items that were missed were of a non-ordnance nature.

In general, these items were missed either due to the presence of geological anomalies that were not able to be filtered out due to there close proximity to the surface, or they had no magnetic anomaly.

##### **3.1.3 Scenario 3**

The following ordnance items were missed in this Scenario:

Mk-118 Rockeyes	missed 6 of 19 total	(68%)
M32 Bomblets	missed 11 of 19 total	(42%)
M38 Bomblets	missed 7 of 33 total	(79%)
M42 Submunitions	missed 3 of 25 total	(88%)

No other ordnance items were missed in the initial interpretation, all other items that were missed were of a non-ordnance nature.

The items that were missed were general in the area that was not surveyed by the EM-61. These items appeared to have only a very small magnetic signature and if there occurred in an area of some geological influence then they would not be able to be

interpreted. There were a number of items that had a very small EM anomaly and these would have been missed, even if the whole area was surveyed with EM.

#### **3.1.4 Scenario 4**

All items that were buried on the 20 sites investigated by ADI were located in the initial interpretation process. As the blocks surveyed had an aerial extent, there were also a number of other control items located but were not interpreted.

The results of this Scenario were very encouraging as ADI interpreted 17 of the 20 sites correctly as ordnance items. The depth calculations also interpreted by ADI were generally very close to the actual depth, being generally within 0.2 metres, except for two sites where the difference was around a meter. Generally ADI defined the class and size of large items correctly but when it came to the smaller items, there was some variation from the control description.

#### **3.1.5 Depth Information**

A summary of the depth information provided and the interpreted depths was undertaken to determine the accuracy of the interpreted depths.

A Chart, see Appendix 5 shows the spread of interpreted depths against actual depths. From the chart it can be seen that the interpreted depths are generally greater than the actual depths by a factor of approximately 25 percent. However, in the very shallow area, ie. 0 to 0.4 metres, the interpreted depth was out by as much as 100 percent.

With the present processing package used by ADI, AGSProc, from AGS Advanced Geophysical Systems GmbH. (Mr. Stephen Lee) from Berlin in Germany, these results have improved substantially and the depths obtained on the control items were generally within 5 to 10% of the true depth.

#### **3.1.6 Summary Table of Results**

The table in Appendix 3, summaries the numbers of the various ordnance items and the magnetics and EM responses over them. The cells in reverse color are the maximum numbers of occurrences of the geophysical response for that particular item.

Scenario 4 has not been included in this table as it was primarily designed for the discrimination task. It should be noted that EM was only run over Scenario 3 (covering only approximately 2/3rds of the areas) and 4.

### **3.2 Gifford Integrated Science Data Analysis**

The Gifford analysis of the results has been included in Appendix 6, and therefore no discussion of the results will be undertaken in this section.

### **3.3 Geosoft Data Analysis**

The Geosoft data was only analysed visually, however, it depended on the level of cut-off used in the refining of the targets as to how many anomalies were present on the grid and therefore how many lined up with the control items. The thresholds used for each of the grids were chosen as a first estimation and further work would be required in determining the most

---

suitable threshold to use for each area. This would include the use of buried control items before proceeding with the survey.

### **3.3.1 Scenario 1**

Most items located by ADI on its initial interpretation were picked by the Geosoft UXO package. All items that were missed by ADI were also missed by the Geosoft package, therefore were either non-magnetic or the remnant magnetic field cancelled out the change to the total field.

Of the 121 control item buried on this site, the Geosoft package located 99 of them, giving an 82 % hit rate.

### **3.3.2 Scenario 2**

On Scenario 2, the Geosoft package would have picked up a number of control items missed by the ADI interpretation however there were a number of control items that were interpreted by ADI but missed by Geosoft. A number of these were very clear distinct anomalies on the analytic signal image. There will need to be further investigation on these points by Geosoft.

Of the 117 control items buried on this site, the Geosoft package located 110 of them, giving a 94% hit rate.

### **3.3.3 Scenario 3**

Scenario 3, being the submunitions range, had similar results to Scenario 1 and 2. Most items that were not located in the ADI interpretation were not located with the Geosoft package. There were a number of the control items that were located by ADI's interpretation that were not located by the Geosoft package.

Of the 137 control items buried on this site, the Geosoft package located 107 of them, giving a 78% hit rate. It should be noted that 22 of these items were in the area not surveyed by the EM-61. ADI believe that this hit rate would have been substantially higher had the EM-61 covered the whole site.

### **3.3.4 Scenario 4**

On this Scenario, the magnetics data was only collected in a 6 meter swath centring on the known point. On a number of these sites, because the item was close to the end of the block, the algorithms for determining the position of the items were not able to locate them due to lack of grid points. This meant that items 1224 and 1242 were not located with the Geosoft package.

#### **4. CONCLUSION**

From a review of all the data, most of the control items that were missed were due to no magnetic anomaly being associated with them or if there was a magnetic anomaly, then it was very small. If ADI had interpreted down to that level then there would be considerably more false alarms.

Most items that were missed were small or had only a small amount of ferrous material present in it.

From the results observed, there would be strong recommendation for undertaking such surveys with two techniques, such as magnetics and electro-magnetics if the targets are going to be small and within the top one meter of the surface. This became very apparent on the Grenade and Submunitions range where the EM assisted the magnetics interpretation greatly and it was clear where there was no EM data collected over part of the Scenario.

There is also a good argument to use two techniques for the processing and interpretation of the results as this would confirm whether items had been missed by one of the processes.

The major concern with using two techniques and two methods of processing would be the cost associated with it. This would double (in general terms) the cost of the survey which in a large number of sites would make the project uneconomical.

The results obtained with the Geosoft UXO package were encouraging, however, there is further work to be undertaken to determine a good picture of suitable threshold to be used in particular areas. There are also a number of anomalies that were present on the analytic signal image that were not interpreted by the Geosoft package and this also will need further investigation.

# **Appendix C: A Portion of the ENSCO, Incorporated Self Assessment Report**

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**Jefferson Proving Ground  
UXO Technology Demonstration Program  
Demonstrator Self-Assessment  
Part 2**

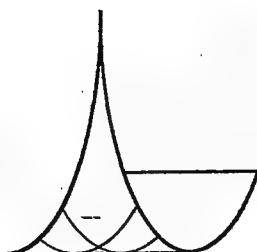
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*Submitted to*

**U.S. Army Engineer Waterways Experiment Station  
Contract No.  
DACA39-98-C-0008**

**December 29, 1998**

*Prepared by:*  
**ENSCO, Inc.**  
**5400 Port Royal Road**  
**Springfield, VA 22151**  
**(703) 321-9000**



#### **4.0 Lessons Learned**

This self assessment provided a means to understand why we were consistently successful in detecting 70 percent (or greater) of the ordnance targets in each of the three scenarios. Our analyses have provided insight into why we missed certain targets and how we can lessen these errors in the future.

Ordnance targets in the AMR, AGR, and IBA that we experienced difficulties in detecting were:

- 1). 60-mm mortar greater than 0.28 meters deep
- 2). 105-mm projectile greater than 0.49 meters deep
- 3). All 2.75-in rocket motors
- 4). All 5-in rocket motors

Non-ordnance targets in the AMR, AGR, and IBA that we experienced difficulties in detecting were:

- 1). All 60-mm mortar tail fins
- 2). Banding material
- 3). Construction material
- 4). Engineers stakes and georods
- 5). Various sizes of ordnance fragments

All of these targets exhibited a very low magnetic response when surveyed with our *MagnaLog* sensor. We initially offered 4 possible explanations for the detection difficulties of the aforementioned targets. Two explanations hold the greatest merit for quantifying our detection difficulties. First, the metallurgy of the target is such that there is minimal ferrous content as to make the target undetectable via conventional magnetic methods, or secondly the target was emplaced at a depth sufficient to be undetected by the deployed sensor system.

Positioning errors with time-sampled data are an important concern. We identified 6-7 targets that may have been located more precisely if we had placed a marker midway along our data collection profiles. We showed, through our analyses, that lateral positioning errors were not as troublesome as in-line positioning errors. Also, we showed that many of our false detections occurred in heavily vegetation. We conclude (and speculated during data acquisition) that these areas would show high false detection rates due to the operator pushing to maintain a steady walking speed in rough terrain. This is a defect of time-sampled data. Real-time spatial positioning systems are needed to improve sensor data quality. This becomes an even more important issue when acquiring data with different sensors, which must be "fused" or jointly interpreted to generate a final result.

Our GPR data on the whole was less helpful than expected. We anticipated that the GPR data would provide clear delineation on the target's azimuth and declination. As we later determined, the 4 profiles we collected per target location often did not provide a clear image of the subsurface target. Our data collection approach was too generalized for the size of targets and their respective depths to glean useful quantitative metrics. Collecting time-sampled data over a fixed profile length created enough bias in the reflection profiles to prohibit a thorough understanding of the resulting GPR profile. We chose our approach based on time, manpower, and financial constraints. Future data acquisition efforts should use quantitative station spacing, multiple polarizations, and more careful analysis of antenna selection.

When we were analyzing data in the IBA, we came upon several conflicts between magnetic dipole orientations and apparent target orientations seen in GPR data. At that time, we tended to report the magnetic azimuth, declination, and depth estimates. In hind-sight, when the GPR data was interpretable, it provides a much more reliable estimate of the geometry of the target. While magnetic dipoles can correspond to target orientations, it was not found to be generally the case for these data.

Based on our analyses we would incorporate electromagnetic methods into future survey activities. Because many targets exhibit low ferrous content, magnetic sensors, even gradiometers, do not detect certain classes of ordnance. We would also look more closely at the magnetic amplitude information. By increasing our target selection threshold we could reduce our false alarms by almost 20% (Scenarios 1 & 2). We would also be more cautious in surveying in brushy areas where 44% of our false alarms existed (not incorporating non-ordnance targets).

We continue to believe that GPR is the key to achieving characterization of UXO in the field. Magnetics and electromagentics provide too little quantitative information to distinguish real targets from false or unimportant targets. Better use of GPR will require both improved data acquisition methods and improved interpretation methods.

The JPG-III ATD has shown that several demonstrators are able to detect a high percentage of existing targets, both UXO and non-UXO. Although detection capabilities are not 100% assured, we are moving in that direction. The faster an area can be surveyed with the assurance of 100% spatial coverage and detection the more time will be available to characterize the detected targets.

In our opinion, the most significant deficiency in the conduct of the JPG-III ATD was that the demonstrators had no prior knowledge of the UXO targets that were emplaced at the site. While we could look-up target sizes/shapes in various references, we had no direct knowledge of the types of targets and their geophysical responses that were buried on-site. At any given range remediation effort, there is always a wide range of uncertainty as to what types of non-UXO items may exist at a site. But, the UXO types that exist on a given range are known and can be evaluated prior to conducting geophysical surveys. Therefore, we recommend that at future ATDs, at a minimum, survey teams be allowed to evaluate the types of UXO expected at a particular site so that optimum survey sensors and parameters can be selected. For example, at JPG-III, if we had known the 60-mm mortar was so weakly ferrous, we would have included electromagnetic sensors.

Overall, we believe JPG-III provided a useful demonstration of capabilites to detect UXO. If we were to repeat the exercise, we believe we could perform significantly better due to our lessons learned.

# **Appendix D: A Portion of the Geo-Centers, Incorporated Self Assessment Report**

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**PART II - TECHNICAL REPORT  
GC-TR-99-3226**

**CRITICAL SELF-ASSESSMENT OF  
JEFFERSON PROVING GROUND  
TECHNOLOGY DEMONSTRATION  
PHASE III (JPGIII) DATA  
(Contract DACA39-98-C-0007)**

*Prepared for*

U. S. Army Engineer District, Vicksburg, CE  
Attn: CEMVK-CT-T (Michael Lee)  
4155 Clay Street  
Vicksburg, MS 39180-3435

*Prepared by*

GEO-CENTERS, INC.  
7 Wells Avenue  
Newton Centre, MA 02459  
(617) 964-7070

**January 1999**

#### **4.0 MISSED TARGET ANALYSIS**

Each scenario was reviewed in detail, with each missed target identified with a position (cross hair) and description (text) overlay. The data around these locations was examined to determine why the target was not detected or reported including signals below the analyst's threshold, missed area (no sensor data there), complex or compound signatures, and possible navigation errors. In addition, target declarations with a location halo (horizontal range) of greater than 1 meter were each examined to see if the anomaly reported matches the truth target description or more likely represents a different, local background object.

The analyst typically analyzed each anomaly with a signature greater than + or - 10 gammas or millivolts (mV). This is just above the typical noise floor for STOLS®. In areas where the noise is low, this threshold may be reduced. Image data was reviewed at a detailed scale of +/- 30 (gammas or mV) out of a possible range of +/- 37,000.

Because the EM sensors were mounted 1.7 meters in front of the vehicle, and the magnetometers were towed 4.5 meters behind the tow vehicle, each sensor system traveled different paths whenever a turn was made. This means that the sensor coverage for each system is different (each had its own DGPS antenna and receiver) around trees and other site obstacles. If a missed target's truth location falls inside a sensor missed area, it is so noted. If the reason for the missed area is other than obstacle avoidance, it is so stated (e.g. bad navigation area).

Geology or proximity to other test targets or unknown background objects often complicates target signatures. Where these situations exist as a contributing factor to a missed target, it is reported.

Overall, the DGPS performed well. There were portions of the site that were wooded enough to block access to satellites or interfere with the reception of the Differential corrections. Loss of satellite access causes gaps in position data, while loss of differential link causes jumps in the reported position data. If these gaps or jumps are small, they are corrected. If they become too severe, the survey data is decimated to only that data with good position data. Where bad navigation position data contributed to a sensor missed area or poor data mapping, it is reported.

Our primary experience is using magnetometers to detect, locate, and characterize UXO. The newly added concurrent EM data acquisition capabilities preceded our ability to process and analyze EM data. As such, there is a strong reliance on the magnetometer data. Where there are both MAG and EM targets in the same area, it is the MAG location that is reported. Where this default criterion affected our results, it is reported.

In general, having access to the target truth table did improve our traditional data processing. A total of five (5) additional UXO targets (two in scenario 2, and three in scenario 3) could be visually detected and reported, given the truth table information. This would have improved our probability of detection from 0.93 to 0.96 for scenario 2, and from 0.91 to 0.94 for

scenario 3, with a combined scenario Pd from 0.93 to 0.95. Additionally, a net increase of eight (8) detectable clutter objects (two in scenario 1, 3 in scenario 2, and 3 in scenario 3) can now be reported, given the ground truth. The net affect here was to increase our false alarm ratio for scenario 1 from 6.3 to 6.37, but decrease our false alarm ratio for scenario 2 from 6.1 to 5.95, and for scenario 3 from 4.00 to 3.90, with a combined scenario false alarm ratio from 5.18 to 5.10. These results show that the traditional STOLS® operator interactive data processing is at or very near its maximum capability. It should be noted that our standard STOLS® data processing has no UXO/Non-UXO discrimination capability, other than a trained operator's experience. This results in declaring most detected anomalies as UXO and therefore produces a higher false alarm rate. Table 4.0 summarizes these results.

**Table 4.0 – Comparison of Original and Standard Data Processing, Given Ground Truth**

Note: - a = original JPGIII results, - b = standard data processing results, given ground truth

	# Baseline	# Detected - a	# Detected - b	Pd - a	Pd - b	False Alarm Ratio - a	False Alarm Ratio - b
<b>Scenario 1</b>							
UXO	43	43	43	1.00	1.00		
Non-UXO	77	63	65	0.82	0.84		
Total	120	106	108				
False Alarms	271	274				6.30	6.37
<b>Scenario 2</b>							
UXO	67	62	64	0.93	0.96		
Non-UXO	50	46	49	0.92	0.98		
Total	117	108	113				
False Alarms	378	381				6.10	5.95
<b>Scenario 3</b>							
UXO	98	89	92	0.91	0.94		
Non-UXO	39	24	27	0.62	0.69		
Total	137	113	119				
False Alarms	356	359				4.00	3.90
<b>Combined Scenarios</b>							
UXO	208	194	199	0.93	0.95		
Non-UXO	166	133	141	0.80	0.85		
Total	374	327	340				
False Alarms	1005	1014				5.18	5.10

#### 4.1 Scenario 1- Aerial Gunnery Range

No UXO targets were missed in this scenario, only clutter items were unreported.

##### Missed clutter objects:

There are 14 missed clutter items in this scenario. Three of these can now be detected, given ground truth. One clutter object credited as "a detect" is truly not at the truth location and would now be reported as a false alarm, but not credited as a truth clutter target detect.

Truth target 260, two 55-gallon drums with lids, was not reported. There is a weak MAG signal (+4, -5) and a weak negative EM signal (-9) that were not analyzed. These signatures do not appear normal, as STOLS has detected a single 55-gallon drum at depths of 4.6 meters (15 feet). It is possible that the individual drum magnetic signatures tended to cancel each other.

Truth target 327, construction material, was not reported. There is no MAG or EM signal there.

Truth target 328, engineer stakes, was not reported. There is no MAG or EM signal at that location. The location is just N of an EM missed area, but there is no indication of an anomaly.

Truth target 329, fragment material, was not reported. There is no MAG signal there. Two MAG anomalies were reported near this truth location. GEO Target 196 is 1.6 meters SW and GEO Target 197 is 2.4 meters NE. A weak EM signal (+8) was not picked. Although GEO target 196 is within the 2-meter detection halo, it does not appear to be associated with the truth location. This target was manually moved into the missed target part of the list.

Truth target 334, fragment material, was not reported. There is no MAG data at that end of the line due to a missed area caused by terminating the storage of data before the sensors reached the end of the site. There is no EM signal there, with a small missed area S of the truth location. GEO target 190 is the closest reported target, about 2.7 meters NW.

Truth target 337, banding material, was not reported. There is no MAG or EM signal at this location.

Truth target 339, fragment material, was not reported. There is no MAG signal at this location and only a weak (-7) EM signal that looks more like system noise than a target of interest.

Truth target 344, construction material, was not reported. There is a weak, distributed magnetic signature (+0, -5) which is considered our noise floor. There is a small missed area in the EM data at this location, with no indication of an EM signal.

Truth target 349, banding material, was not reported. There is no MAG signal at that location. There is an EM missed area (no data) at that location with no indication of an anomaly near by.

Truth target 352, fragment material, was not reported. There is no MAG signal at this location and no EM signal. The truth location is on the edge of an EM missed area, but there is no indication of an anomaly present.

Truth target 361, banding material, was not reported. There is no MAG or EM signal at this location. There is a below threshold, negative EM signal 1.4 meters SW of the truth location that was not selected.

Truth target 366, construction material, was not reported. The magnetic signature around the truth location shows an extended object with a predominately negative MAG signature (-20 to + 4). Due to its extended nature, it was not selected as UXO. There is no corresponding EM data over this area (EM missed area) on the southern edge of the site.

Truth target 415, geo rods, was not reported. There is no MAG signal there. GEO Target 209 is 2.5 meters N of the truth location. A weak negative EM signal (-5) was not picked.

Truth target 1861, 600 x 200 x 2, was not reported. There is a weak MAG signal (+12 gammas) 0.8 meters NW of the truth location. There is also a weak EM signal (+13) 1 meter W of the truth location. Neither anomaly was selected for analysis. Analyzing the data around the truth location does report a small target, so this target is manually moved up to the detect part of the list. GEO target 118 was reported 2.008 meters SW of the truth location, but is outside the 2-meter detect halo.

Truth target 1893, 125 x 50 with Base Plate, was not reported. There is a MAG missed area and no EM signal there.

#### **4.2 Scenario 2 – Artillery and Mortar Range**

##### **Missed UXO targets:**

Five UXO items were not reported for this scenario. Two of the five missed UXO items may have been picked given the truth location data by analyzing EM data below the analyst's threshold. Truth target 1203 is in a noisy EM area and was not picked. Truth target 1181 has a weak EM signal 1.7 meters S of the truth location, so it falls into the 2-meter detection halo, but may not be the truth target.

Truth target 1163, 60 mm mortar, was not reported. There is no MAG signal there and the EM signal is noisy at this location, so no target was picked. It is most likely that the burial parameters are too severe for reliable detection.

Truth target 1167, 60 mm mortar, was not reported. There is no MAG or EM signal at this location. It is most likely that the burial depth of 0.61 meters is too deep for reliable detection.

Truth target 1181, 105 mm projectile, was not reported. There is a negative MAG signal (-12) 1.2 meters N of truth location and a positive EM signal (+12) 1.7 meters S of this location.

Neither anomaly was picked, but this target is manually moved up to the detect part of the list, given the ground truth input.

Truth target 1195, 105 mm projectile, was not reported. There is a weak negative MAG signal (-13) and no EM signal. Generally MAG anomalies for objects buried deep (1.03 meters in this case) for their size, only the positive portion of their magnetic signature are mapped. Negative only signatures generally indicate an object above the plane of the sensor (above ground). Therefore this anomaly was not picked.

Truth target 1203, 60 mm mortar, was not reported. There is no MAG signal and noisy EM signal (+16) that was not picked.

\*\* Truth targets 1210, 60 mm mortar, target 1384, 81 mm mortar – Illumination, and target 1386, 81 mm mortar were picked using MAG data when they would have been better located using the available EM data.

#### Missed clutter objects:

There were four (4) missed clutter targets in this scenario. Three of these clutter objects would be reported given the ground truth.

Truth target 249, banding material, was not reported. There is a negative MAG signal (-15) at this location that was not picked. Negative only signatures generally indicate an object above the plane of the sensor (above ground). There is no EM signal.

Truth target 1298, 250 x 100 x 13, was not reported. There is no MAG signal at this location, though GEO Target 1431 is 2.1 meters N. A better EM signal (+23) is present at the truth location, but the nearby MAG target took precedence, but is moved up to the detect part of the list, given the ground truth.

Truth target 1380, fragment – 60-mm mortar, was not reported. There is a weak MAG signal (+10) and a weak EM signal (+12, -8) that were not picked. Analyzing the MAG data around the truth location does pick the anomaly, given the ground truth.

Truth target 1382, fragment 60 mm mortar, was not reported. There is no MAG signal and only a weak EM signal (+14) that was not picked, but is detectable given the ground truth.

#### **4.3 Scenario 3 – Grenade and Submunition Range**

##### Missed UXO targets:

Three UXO targets detected in this scenario (truth targets 1620, 1678, and 1776) would have been better reported using the available EM signature. There were 10 missed UXO items in

this scenario. Three of these missed UXO items (1654, 1676, and 1716) would be reported, given the ground truth. One UXO target (1728) has a GEO target (2414) within the 2-meter detection halo, but is most likely not associated with the reported anomaly.

Truth target 1636, M32 bomblet, was not reported. There is no MAG or EM signal at this location.

Truth target 1654, M42 submunition (HEAT), was not reported. There is a weak MAG signal (+5, -2) and no EM signal. Analyzing the data around the truth location does get a MAG target pick (manually moved up).

Truth target 1676, M42 submunition (HEAT), was not reported. There is no MAG signal in this area that is geologically active. There is a weak EM signal (+6) that was not picked, but is now moved to the detect part of the list, given the ground truth.

Truth target 1716, M42 submunition (HEAT), was not reported. There is no MAG signal and only a weak EM signal (+6, -6) that was not picked but would now, given the ground truth.

Truth target 1722, M38 bomblet, was not reported. This location is also a poor navigation area that caused a MAG missed area at the target location. The EM nave. was also poor in this area, but no signal is observable at the truth location. The EM data around this location shows a streak in one of the EM channels, most likely due to a low battery.

Truth target 1726, M42 submunition (HEAT), was not reported. This location is in an area where the nave. data was very poor and caused a MAG missed area. There is no EM data at that location. Since STOLS® detected other M42 submunitions at deeper depths and at the same orientation and inclination, it is expected that this target would have been reported, given better nave. data. Recorrecting the original nave. data did not produce any better sensor detection.

Truth target 1728, M32 bomblet, was truly not detected. GEO target 2414 is 1.8 meters S, but does not appear to be the truth target signature. The truth location is on the edge of a MAG missed area with no indication of a MAG anomaly. There is a very weak EM signal (+5) that was not picked. This target was manually moved to the missed target part of the list.

Truth target 1732, M32 bomblet, was not reported. There is no MAG or EM signal at this location.

Truth target 1742, M32 bomblet, was not reported. There is no MAG signal and only a weak negative EM signal (-5) that was not picked.

Truth target 1758, M32 bomblet, was not reported. There is no MAG or EM signal there.

Missed clutter objects:

There were fifteen (15) unreported clutter targets in scenario 3. Three of these missed clutter objects show sufficient visual signal strength to now be detected, given ground truth.

Truth target 414, geo rods, was not reported. The truth location is inside a large positive MAG shadow (+16 to +21) that does not indicate the presence of another, compound object. There is no EM signal there.

Truth target 416, geo rods, was not reported. There was no MAG or EM signal at that location.

\*\* Truth target 1794, 100 x 25 x 13, was reported as GEO target 2214, 1.8 meters W of truth location. Analyzing the MAG data around the truth location brings the location range to 1.0 meter. There is no EM signal there.

Truth target 1808, 125 x 25 x 10, was not reported. There is a weak MAG signal (+9) that is in the shadow of a larger positive only MAG signature to the S of the truth location. This background signal could be geological. There is a very weak negative EM signal (-4) around a small EM missed area at the truth location.

Truth target 1812, 75 x 50 x 10, was not reported. There is no MAG signal and only a weak EM signal (+5) that was not picked.

Truth target 1814, 100 x 50 x 10, was not reported. There are MAG and EM missed areas due to poor nave. There is a very weak EM signal (+3) 1.6 meters N of truth location that was not picked.

Truth target 1818, 100 x 25 x 10, was not reported. There is no MAG signal and only a very weak EM signal (+4) that was not picked.

Truth target 1822, 100 x 25 x 3, was not reported. There is no MAG or EM signal there. The MAG data is low (-14) due to local geology.

Truth target 1825, 100 x 25 x 3, was not reported. There is no MAG signal and an EM missed area with no indication of an EM anomaly.

Truth target 1828, 75 x 19 x 3, was not reported. There is no MAG signal and a small EM missed area with no indication of an anomaly.

Truth target 1833, 75 x 35 x 3, was not reported. There is no MAG or EM signal at this location.

Truth target 1833, 75 x 35 x 3, was not reported. There is no MAG or EM signal at this location.

Truth target 1835, 75 x 25 x 3, was not reported. There is no MAG or EM signal there. There are small MAG and EM missed areas close to the truth location, but are not responsible for the miss.

Truth target 1837, 75 x 25 x 3, was not reported. There is no MAG signal and only a weak EM signal (+5) that was not picked.

Truth target 1839, 100 x 25 x 3, was not reported. There is no MAG signal there, and only a weak negative EM signal (-7) that was not picked.

Truth target 1841, 100 x 25 x 3, was not reported. There is no MAG or EM signal there.

Truth target 1843, 50 x 25 x 3, was not reported. There is a very weak MAG signal (-4) S of the truth location and a very weak EM signal (+3) W of the truth location. Neither one was picked.

## 5.0 Enhanced Data Processing to Discriminate Ordnance from Non-Ordnance

Program activities that were conducted under this task included:

- The extraction of data features from representative magnetometer and EM sensor signatures collected during the JPGIII field operation.
- The analysis of the extracted features.
- The development of UXO and Clutter Prototypes based on the feature analyses.
- Fuzzy distance measurements to both the UXO and Clutter Prototypes.
- Development of an ordnance classification system based on the fuzzy distance measurements.
- The development of a fuzzy inference system for classifying potential targets as UXO or Clutter.

The work that was performed in this area was conducted using a sub-class of the emplaced items that were surveyed during the JPGIII field operation. This sub-class included all of the 60 mm mortars, 81 mm mortars, 4.2 inch mortars, 76 mm projectiles, 81 mm projectiles, 105 mm projectiles, 152 mm projectiles, and 155 mm projectiles that were surveyed during GEO-CENTERS' JPGIII field operations. In total, there were 61 ordnance items included in this sub-class. In addition, 50 representative emplaced clutter items that were surveyed during GEO-CENTERS' JPGIII field operations were additionally selected and included in the sub-class. The clutter items included were many of the emplaced plates, 155 mm projectile base plates, 81 mm fragments, 152 mm debris, 105 mm debris, 60 mm fragments (tail fins), 81 mm fragments (nose cones and tails and fins), 90 mm casings, and a variety of emplaced clutter items that were listed in the ground truth as ordnance fragments (one of these items was specifically listed as a crushed 105 mm projectile). This sub-class of 111 targets acted as both the training and evaluation sets for the different methods explored under this program. However, it should be noted that the

# **Appendix E: A Portion of the GTL Self Assessment Report**

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**GEOPHYSICAL TECHNOLOGY LIMITED**

ACN: 072 470 243

P O Box U9  
Armidale NSW 2351  
AUSTRALIA

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Response by  
**Geophysical Technology Limited**  
To  
U.S. Army Corps of Engineers  
Waterways Experiment Station  
Reference  
Contract No: DACA39-98-C-0006

**The Jefferson Proving Ground UXO Technology  
Demonstrator Self-Assessment**

***Part 2***  
***Critical Self-Assessment of Performance***

**Submitted to:** El-Environ Sensing Branch  
U.S. Army Corps of Engineers  
Waterways Experimental Station  
3909 Halls Ferry Rd  
Vicksburg MS 39180-6199

**Date:** 28<sup>th</sup> January, 1999

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The Jefferson Proving Ground UXO Technology  
Demonstrator Self-Assessment

***Part 2***

***Critical Self-Assessment of Performance***

**1. INTRODUCTION**

GTL (formerly the Geophysical Research Institute of the University of New England, Australia), demonstrated its proprietary UXO detection and sub-surface mapping technologies at Jefferson Proving Ground, Madison, Indiana, from 9 to 13 October, 1996.

The complementary TM-4 magnetometer and TM-4 $\epsilon$  pulsed electromagnetic induction technologies were demonstrated at sites typical of an "Aerial Gunnery Range", an "Artillery and Mortar Range" and a "Grenades and Sub-munitions Range". For each scenario three results were submitted. A magnetics only result, an electromagnetics only result and a combined (data fused) result.

Part 1 of this report described what data acquisition and interpretation processes were used when the JPG(III) technology demonstration (TD) was conducted. Having thus defined what was actually done for JPG(III), the objective of the Self Assessment is to use the baseline data to identify the strengths and deficiencies of the procedure adopted at that time, and if possible, propose how those strategies might be improved in the future. Some of the required improvements have now already been implemented. Other improvements required may be identified as future tasks awaiting funding, while others may be seen as perhaps limited by present hardware technology and not likely to be overcome in the short term.

This Part 2 report describes the results of an analysis by GTL of their own performance. The government first scored GTL's performance by comparing our reported detection and interpretation data against their baseline data set. The objective of this analysis is to determine why differences between the two occurred so that improvements to the detection and data analysis technology may be achieved in the future. The report also describes the technical advances that GTL has implemented since the JPG(III) demonstration partly in response to feedback from its own development program but also through the benefit derived from the opportunity to participate in this self-assessment program.

**2. PROJECT MANAGEMENT**

Overseeing this assessment project was Dr John M Stanley, GTL's Managing Director. Peter J Clark and Stephen M Griffin performed the assessment.

### 3. ANALYSIS OF PERFORMANCE

Our analysis of performance has focused upon the three parameters of "detection", "typing" of detected targets as UXO or non-UXO and of "discrimination" against sources of false alarm. As GTL participated in the three scenario sites of "Aerial Gunnery", "Artillery and Mortar" and "Grenades and Sub-munitions", a performance analysis has been conducted for each. GTL demonstrated a combination of magnetic and electromagnetic detectors. It submitted the results of each method individually and it submitted a combined interpretation based upon a data fusion strategy. Consequently, our analysis has been set out to quantify the performance of each detector and the data fusion process.

#### 3.1 Detection Results

The following sections identify those baseline targets that GTL failed to report and it identifies the reason for this occurring. Items that GTL detected but did not report for some reason, were officially scored as "not detected". The reason for not reporting an item that was in fact detected is an important aspect in the analysis of detection results as scored.

##### 3.1.1 Scenario 1: Aerial Gunnery

The detection performance achieved by GTL's detectors and data fusion strategy at the Aerial Gunnery Scenario area may be summarised as follows:

Aerial Gunnery					
	Number of Baseline Targets	Number Reported From EM Survey	Number Reported From Mag. Survey	Number Reported From Fused Survey	Number Not Reported From Fused Survey
Ordnance	43	32 (74%)	38 (88%)	41 (95%)	2
Non-Ordnance	77	62 (81%)	72 (94%)	69 (90%)	8
Total	120	94 (78%)	110 (92%)	110 (92%)	10

Analysis of the UXO targets not reported has been tabulated as follows:

Target Key No.	Description	Depth (m)	Detect by EM?	Detect by Mag?	Reason for Failure to Report
1858	2.75" rocket motor	0.48	Yes	No	To be defined as UXO, GTL understood a rocket must include the explosive head.  The combined EM and Magnetic responses recorded were not compatible with those of a rocket head or other aerial gunnery baseline item and were therefore not reported as an item from the nominated baseline list.
1857	2.75" rocket motor	0.41	Yes	No	As above

Analysis of the Non-UXO targets not reported has been tabulated as follows:

Target Key No.	Description	Depth (m)	Detect by EM?	Detect by Mag?	Reason for Failure to Report
361	banding material	0.50	No	Yes	None. Inadequate description of "banding material" made available to GTL.
352	fragment material	0.13	No	No	None. Inadequate description of "fragment material" made available to GTL.
349	banding material	0.31	No	No	None. Inadequate description of "banding material" made available to GTL.
339	fragment material	0.59	No	No	None. Inadequate description of "fragment material" made available to GTL.
1869	300x50x3 frag	0.28	Yes	Yes	Under-developed data fusion algorithm.
337	banding material	0.20	No	No	None. Inadequate description of "banding material" made available to GTL.
327	construction material	0.23	No	Yes	None. Inadequate description of "construction material" made available to GTL.
415	georods	-1.00	No	No	Believed to be non-metallic, no details made available to GTL.

From these results we can further summarise that:

- Of the 43 UXO targets present:
  - Magnetic interpretation alone reported 38 (88%)
  - Electromagnetic interpretation alone reported 32 (74%)
  - Magnetic and Electromagnetic combined interpretation reported 41 (95%)
  - Of the 2 items not reported in the combined result as detected:
    - Both targets were detected. However, GTL understood that to be defined as UXO, a "rocket" must include the warhead. The relationship between the EM and Magnetic responses recorded was not compatible with that of a rocket head or other aerial gunnery baseline item and these targets were therefore correctly rejected by the data fusion process and not reported as an item from the nominated baseline list. Had rocket motors minus head been considered as a possible baseline target we would have reported these targets, and achieved a 100% detection score on this scenario.  
*How would you accomplish this?*
- Of the 77 Non-UXO targets present:
  - Magnetic interpretation alone reported 71 (94%)
  - Electromagnetic interpretation alone reported 62 (81%)
  - Magnetic and Electromagnetic combined interpretation reported 69 (90%)
  - Of the 8 items not reported in the combined result as detected:
    - One target that was detected was rejected from reporting as a result of a deficiency in the development of the data fusion algorithm. This has since been rectified.
    - Two further targets that were detected with magnetics were rejected as possibly being UXO on the basis that the target was non-metallic. While ceramic building bricks for example will be magnetic and non-metallic, we would not consider them to be potential UXO and we believe we were correct in not reporting these. The description "construction material" is inadequate for drawing any further conclusions from this result.

The conclusions that can be drawn from the Aerial Gunnery section of the analysis are:

- GTL believe that to be defined as a baseline UXO target a "rocket" had to include the explosive warhead and that this misunderstanding was the only reason we did not achieve a 100% UXO detection score on this scenario.
- We are unable to draw conclusions regarding 6 of the 8 non-UXO targets that we failed to report due to inadequate description of what these items were. For example, if "building material" was solely non-metallic, our failure to report it would have been seen by us as a positive performance whereas if it included reo-bars for example at 0.23 m depth then failure to report this would be regarded as serious and requiring explanation.

- In spite of a error in our algorithm the fusion of data from both the magnetometer and TM-4ε EM system produced a detection outcome that was better than that of either sensor in isolation. Allowing for the misunderstanding regarding a rocket motor minus explosive head being classified as UXO, data fusion increased the detection from 88% (magnetic only) and 79% (electromagnetic only) to 100% combined.
- The performance of the TM-4ε in detecting Aerial Gunnery targets would be improved by lowering the interpretation threshold. The implementation of recent improvements in processing the EM data enable the interpretation threshold to be lowered without increasing the false alarm rate. Analysis of this data has determined that lowering the interpretation threshold by one half results in increasing the UXO detection from 32 (74%) to 38 (88%) at this scenario without altering the false alarm rate. The detection of non-ordnance remained unchanged.
- The performance of the magnetometer in detecting Aerial Gunnery targets would be improved at this locality by lowering the sensor elevation (and correspondingly reducing the sensor line separation). This is not a general conclusion because it applies only to situations where the source of geological interference is deeper than the targets of interest. Lowering the sensors to 0.25m (with appropriate reduction in line separation) was predicted to increase the magnetic detection performance of UXO from 38 (88%) to 40 (93%) at this scenario and the detection of non-ordnance from 72 (94%) to 73 (95%).

### 3.1.2 Scenario 2: Artillery and Mortar

The detection performance achieved by GTL's detectors and data fusion strategy at the Artillery and Mortar Scenario area may be summarised as follows:

Artillery and Mortar					
	Number of Baseline Targets	Number Reported From EM Survey	Number Reported From Mag. Survey	Number Reported From Fused Survey	Number Not Reported From Fused Survey
Ordnance	67	58 (87%)	62 (93%)	60 (90%)	7 (10%)
Non-Ordnance	50	49 (98%)	41 (82)	50 (100%)	0 (0%)
Total	117	107 (91%)	103 (88%)	110 (94%)	7 (6%)

Analysis of the UXO targets not reported has been tabulated as follows:

Target Key No.	Description	Depth (m)	Detect by EM?	Detect by Mag?	Reason for Failure to Report
1326	81-mm mortar (illumination case)	0.18	Yes	Yes	Under-developed data fusion algorithm.
1181	105-mm projectile	1.06	Yes	Yes	Below EM interpretation threshold, better choice of threshold required.  Below magnetic interpretation threshold, lower sensor elevation required.
1195	105-mm projectile	1.03	Yes	Yes	Below EM interpretation threshold, better choice of threshold required.  Below magnetic interpretation threshold, lower sensor elevation required.
1197	60-mm mortar	0.51	Yes	Yes	Below EM interpretation threshold, better choice of threshold required.  Below magnetic interpretation threshold, lower sensor elevation required.
1203	60-mm mortar	0.69	No	No	Expected to detect with EM. Conclude positional error leaving "hole" in EM coverage. Use DGPS to overcome this.  Too deep for magnetic detection, lower sensor elevation required.
1163	60-mm mortar	0.76	Yes	Yes	Under-developed data fusion algorithm.
1378	81-mm mortar (illumination case)	0.16	Yes	Yes	Under-developed data fusion algorithm.

All Non-UXO targets were reported from the Artillery and Mortar Scenario.

From these results we can further summarise that:

- Of the 67 UXO targets present:
  - Magnetic interpretation alone reported 62 (93%)
  - Electromagnetic interpretation alone reported 58 (87%)
  - Magnetic and Electromagnetic combined interpretation reported 60 (90%)
  - Of the 7 items not reported in the combined result as detected:
    - Three targets that were detected were rejected from reporting as a result of a deficiency in the data fusion algorithm. This has since been rectified.
    - Three ferrous targets that escaped reporting would have been expected to have been reported had a lower sensor elevation been used to enhance the signal to noise ratio. Note this is a site-specific conclusion because at JPG the geological noise source was deeper than the target. In many situations geological noise occurs at the ground-air interface requiring a higher sensor elevation for optimal S/N.
    - Three targets would have been reported had a better choice of interpretation threshold been adopted. More appropriate threshold criteria have since been defined.
    - One target, a 61-mm mortar, should have been detected with the EM but was not. It was most probably missed due to the operator exceeding the permitted ground clearance tolerance or, incomplete coverage with a single sensor (a "hole" in the coverage pattern). A multi-sensor array is currently being developed, which increases the survey swath width and elevation stability, thereby reducing the data positioning tolerance required.
  - Of the 50 Non-UXO targets present:
    - Magnetic interpretation alone reported 41 (82%)
    - Electromagnetic interpretation alone reported 49 (98%)
    - Magnetic and Electromagnetic combined interpretation reported 50 (100%)

The conclusions that can be drawn from the Artillery and Mortar section of the analysis are:

- The performance of the TM-4ε in detecting Artillery and Mortar targets would be improved by lowering the interpretation threshold. The implementation of recent improvements in processing the EM data enable the interpretation threshold to be lowered without increasing the false alarm rate. Analysis of this data has determined that lowering the interpretation threshold by one half results in increasing the UXO detection from 58 (87%) to 63 (94%) at this scenario without altering the false alarm rate while the EM detection of non-ordnance remained at 50 (100%).
- The performance of the magnetometer in detecting Artillery and Mortar targets would be improved at this locality by lowering the sensor elevation (and correspondingly reducing the

sensor line separation). This is not a general conclusion because it applies only to situations where the source of geological interference is deeper than the targets of interest. Lowering the sensors to 0.25m (with appropriately reduced line separation) was predicted to increase the magnetic detection performance of UXO from 62 (93%) to 67 (100%) at this scenario and the detection of non-ordnance from 41 (82%) to 47 (94%).

- In spite of an error in our algorithm the fusion of data from both the magnetometer and TM-4ε EM system produced a detection outcome that was better than that of either sensor in isolation. After correcting the error, data fusion increased the detection from 93% (magnetic only) and 87% (electromagnetic only) to 97% combined, thus justifying the use of the two, complementary sensors.

### **3.1.3 Scenario 3: Grenades and Sub-munitions**

The detection performance achieved by GTL's detectors and data fusion strategy at the Grenades and Sub-munitions Scenario area may be summarised as follows:

<b>Grenades and Sub-munitions</b>					
	<b>Number of Baseline Targets</b>	<b>Number Reported From EM Survey</b>	<b>Number Reported From Mag. Survey</b>	<b>Number Reported From Fused Survey</b>	<b>Number Not Reported From Fused Survey</b>
Ordnance	98	90 (92%)	46 (47%)	93 (95%)	5 (5%)
Non-Ordnance	39	24 (62%)	27 (69%)	28 (72%)	11 (28%)
<b>Total</b>	<b>137</b>	<b>114 (83%)</b>	<b>73 (53%)</b>	<b>121 (88%)</b>	<b>16 (12%)</b>

Analysis of the UXO targets not reported has been tabulated as follows:

Target Key No.	Description	Depth (m)	Detect by EM?	Detect by Mag?	Reason for Failure to Report
1704	Mk118 rockeye	0.17	Yes	No	<p>Below EM interpretation threshold, better choice of threshold required.</p> <p>Not expected to detect with Magnetics because target is non-ferrous.</p>
1676	M42 sub-munition	0.22	Yes	Yes	<p>Below EM interpretation threshold, better choice of threshold required.</p> <p>Below magnetic interpretation threshold, lower sensor elevation required.</p>
1674	M42 sub-munition	0.29	Yes	No	<p>Below EM interpretation threshold, better choice of threshold required.</p> <p>Magnetic signal lost in geological noise. Lower sensor elevation required.</p>
1590	M32 bomblet	0.15	Yes	No	<p>Below EM interpretation threshold, better choice of threshold required.</p> <p>Not expected to detect with Magnetics because target is low-ferrous.</p>
1584	M118 rockeye	0.16	No	No	<p>Expected to detect with EM. Conclude positional error leaving "hole" in EM coverage. Use DGPS to overcome this.</p> <p>Not expected to detect with Magnetics because target is non-ferrous.</p>

Analysis of the Non-UXO targets not reported has been tabulated as follows:

Target Key No.	Description	Depth (m)	Detect by EM?	Detect by Mag?	Reason for Failure to Report
1833	75x35x3 (fragment)	0.09	Yes	Yes	EM interpretation operator error.  Below magnetic interpretation threshold, lower sensor elevation required.
416	Georods	-1.00	No	No	Believed to be non-metallic, no details made available to GTL.
1841	100x25x3 (fragment)	0.20	Yes	Yes	Below EM interpretation threshold, better choice of threshold required.  Below magnetic interpretation threshold, lower sensor elevation required.
1839	100x25x3 (fragment)	0.11	Yes	Yes	As above
1828	75x19x3 (fragment)	0.20	Yes	No	Below EM interpretation threshold, better choice of threshold required.  Magnetic signal lost in geological noise. Lower sensor elevation required.
1812	75x50x10 (frag.)	0.21	Yes	Yes	Under-developed data fusion algorithm.
1814	100x50x10 (frag.)	0.13	Yes	Yes	Under-developed data fusion algorithm.
1843	50x25x3 (fragment)	0.15	Yes	No	Below EM interpretation threshold, better choice of threshold required.  Lower sensor elevation required.
1835	75x25x3 (fragment)	0.17	Yes	No	EM interpretation operator error.  Magnetic signal lost in geological noise. Lower sensor elevation required.
1790	100x75x3 (fragment)	0.33	Yes	No	Below EM interpretation threshold, better choice of threshold required.  Lower sensor elevation required.
414	Georods	-1.00	No	No	Believed to be non-metallic, no details made available to GTL.

From these results we can further summarise that:

- Of the 98 UXO targets present:
  - Magnetic interpretation alone reported 46 (47%)
  - Electromagnetic interpretation alone reported 90 (92%)
  - Magnetic and Electromagnetic combined interpretation reported 93 (95%)
  - Of the 5 items not reported in the combined result as detected:
    - Two ferrous targets that escaped reporting would have been expected to have been reported had a lower sensor elevation been used to enhance the signal to noise ratio. Note this is a site-specific conclusion because at JPG the geological noise source was deeper than the target. In many situations geological noise occurs at the ground-air interface requiring a higher sensor elevation for optimal S/N.
    - Three targets would have been reported had a better choice of electromagnetic interpretation threshold been adopted. More appropriate criteria for threshold choice have since been defined.
    - One target, a non-ferrous rockeye, should have been detected with the EM but was not. It was most probably missed due to the operator exceeding the permitted ground clearance tolerance or, incomplete coverage with a single sensor (a "hole" in the coverage pattern). A multi-sensor array is currently being developed, which increases the survey swath width and elevation stability, thereby reducing the line positioning tolerance required.
- Of the 39 Non-UXO targets present:
  - Magnetic interpretation alone reported 27 (69%)
  - Electromagnetic interpretation alone reported 24 (62%)
  - Magnetic and Electromagnetic combined interpretation reported 28 (72%)
  - Of the 11 items not reported in the combined result as detected:
    - Two were believed to be non-metallic (The TM-4 $\epsilon$  only detects metals)
    - Five targets would have been reported had a better choice of electromagnetic interpretation threshold been adopted. More appropriate threshold criteria have since been defined.
    - Two targets were missed due to operator error, a hazard that has since been overcome by automated processing.
    - Seven ferrous targets that escaped reporting would have been expected to have been reported had a lower sensor elevation been used to enhance the signal to noise ratio.
    - Two targets that were detected were rejected from reporting as a result of a deficiency in the development of the data fusion algorithm. This has since been rectified.

The conclusions that can be drawn from the Grenade and Sub-munitions section of the analysis are:

- The performance of the TM-4 $\epsilon$  in detecting Grenade and Sub-munition targets would be improved by lowering the interpretation threshold. The implementation of recent improvements in processing the EM data enables the interpretation threshold to be lowered without increasing the false alarm rate. Analysis of this data has determined that lowering the interpretation threshold by one half results in increasing the UXO detection from 90 (92%) to 96 (98%) at this scenario and the detection of non-ordnance from 24 (62%) to 31 (80%). The only undetected targets were non-metallic.
- The performance of the magnetometer in detecting Grenade and Sub-munition targets would be improved at this locality by lowering the sensor elevation (and correspondingly reducing the sensor line separation). This is not a general conclusion because it applies only to situations where the source of geological interference is deeper than the targets of interest. Lowering the sensors to 0.25m (with appropriately reduced line separation) was predicted to increase the magnetic detection performance of UXO from 46 (47%) to 52 (53%) at this scenario and the detection of non-ordnance from 27 (69%) to 30 (77%).
- With the implementation of recent improvements in processing the EM data, GTL believe that the TM-4 $\epsilon$  is now capable of detecting and interpreting 99% of the baseline grenade and sub-munition targets at this scenario leaving only those baseline targets that are non-metallic remaining undetected.
- While the fusion of EM and magnetic data improved the reporting performance by 5% as originally submitted, this benefit has since been superseded by improvements in the EM technology. Therefore the acquisition of magnetic data may not generally be considered cost-effective for this scenario.

### 3.2 Typing (UXO and Non-UXO Baseline Targets) Result

At the time of the JPG(III) demonstration program, GTL had just completed its development of the prototype of its TM-4 $\epsilon$  electromagnetic detector. While the ability of this detector to differentiate between UXO and Non-UXO targets was a primary factor in its design specification, GTL had not yet developed this aspect of TM-4 $\epsilon$  signal processing. On the other hand, processing of magnetic data was well advanced and understood. From this knowledge of the magnetic response of UXO and Non-UXO it was recognised that magnetics does not have the potential to reliably type a target as UXO or Non-UXO on the basis of dipole moment.

The approach taken for typing was of necessity, conservative. If a magnetic response did not fall clearly outside the range of expected responses for the baseline items then it was reported as "UXO". Similarly, if the TM-4 $\epsilon$  response did not depart clearly from that expected from a baseline target then it was reported as "UXO". With such elementary criteria upon which to base our typing it was not surprising that our reporting of UXO was relatively accurate while our reporting on Non-UXO was not.

We consider that no further explanation of our typing performance is justified. However, in the period since the JPG(III) demonstration, typing targets as UXO or Non-UXO has been a

development priority and the performance achieved was demonstrated at the recent JPG(IV) demonstration.

### ***3.2.1 Typing, Scenario 1: Aerial Gunnery***

GTL's typing performance at the Aerial Gunnery Scenario is summarised by the following table:

	Number of Magnetic Reports	Number of EM Reports	Number of Combined Reports	Correct Magnetic Typing	Correct EM Typing	Correct Combined Typing
UXO	38	32	41	34 (89%)	32 (100%)	38 (93%)
Non-UXO	72	62	69	4 (6%)	2 (3%)	4 (6%)
Total	110	94	110	38 (35%)	34 (36%)	42 (38%)

### ***3.2.2 Typing, Scenario 2: Artillery and Mortar***

GTL's typing performance at the Artillery and Mortar Scenario is summarised by the following table:

	Number of Magnetic Reports	Number of EM Reports	Number of Combined Reports	Correct Magnetic Typing	Correct EM Typing	Correct Combined Typing
UXO	62	58	60	61 (98%)	57 (98%)	58 (97%)
Non-UXO	41	49	50	3 (7%)	1 (2%)	4 (8%)
Total	103	107	110	64 (62%)	34 (31%)	42 (38%)

### 3.2.3 Typing, Scenario 3: Grenades and Sub-munitins

GTL's typing performance at the Grenades and Sub-munitions Scenario is summarised by the following table:

	Number of Magnetic Reports	Number of EM Reports	Number of Combined Reports	Correct Magnetic Typing	Correct EM Typing	Correct Combined Typing
UXO	46	90	93	46 (100%)	89 (99%)	86 (92%)
Non-UXO	27	24	28	0 (0%)	5 (18%)	10 (36%)
Total	73	114	121	46 (38%)	94 (78%)	96 (79%)

### 3.3 Discrimination (UXO and False Alarms) Result

GTL was officially scored as having a relatively high false alarm rate. The reasons for this have been analysed in detail where information has been available.

Baseline data provided for this assessment of performance is inadequate for the purpose of distinguishing between false negative and false positive alarms. This is because the project managers had no means of knowing what non-baseline metallic items were present on the site.

As previously noted, at the time of the JPG(III) demonstration program, GTL had just completed the development of the prototype of its TM-4 $\epsilon$  electromagnetic detector. The ability of this detector to differentiate between geological sources, UXO and Non-UXO targets was a primary factor in its design specification. At the time of the demonstration, the performance of the TM-4 $\epsilon$  in discriminating against magnetic and conductive minerals in the ground was well developed and very well understood. However GTL had not yet fully developed discrimination between metallic sources that were UXO from metallic sources that were not.

Also as previously noted, processing of magnetic data was well advanced and understood. From this knowledge it was recognised that magnetics does not have the potential to reliably type a target as UXO or Non-UXO on the basis of dipole moment or to distinguish these sources from geological sources displaying a similar dipole moment.

GTL's approach since JPG(III) to reducing false alarm occurrences has been based upon the fusion of data from magnetic and TM-4 $\epsilon$  electromagnetic sensors and upon improving the depth performance of the TM-4 $\epsilon$ . Advances in the TM-4 $\epsilon$  signal processing have facilitated this to the extent quantified by the JPG(IV) demonstration results.

The performance of the TM-4 $\epsilon$  in discriminating against false negative (geological) sources is very well understood. We do know what is the maximum response from the TM-4 $\epsilon$  that could arise from mineralised ground. On this basis, signals exceeding that threshold MUST be metallic in origin and we have now had sufficient experience in proving this to feel confident of this claim.

By contrast, the magnetic method provides little means for discriminating between a magnetic dipole of metallic origin and one of geological origin when the dipole moment is similar. Hence, discrimination against false negative sources occurring at depth greater than the detection depth of the TM-4e remains very difficult. As evidenced by the analysis of detection results in section 3.1, a significant reduction in the false negative score resulting from magnetic data would have been achieved by reducing the sensor elevation above ground thereby substantially increasing the signal to noise ratio of that data.

False positive sources may only be discriminated against by reliable typing. GTL was able to identify many of the false positive sources as non-UXO and we reported these as non-UXO. As the summary tables below demonstrate, a significant contribution to GTL's high false alarm score was due to targets reported by us as non-UXO being scored as false alarms. We consider this to be a fault of the scoring system and a positive attribute of the technology rather than a fault of the technology. As the summaries below record, discounting targets reported as non-UXO would have resulted in a very slightly reduced detection performance (only 1 item) as a result of mistyping UXO as non-UXO. The importance of better technology for typing metallic targets has been well recognised and significant improvements already achieved as demonstrated at JPG(IV).

### 3.3.1 False Alarms, Scenario 1: Aerial Gunnery

Analysis of the false alarms scored against GTL at the Aerial Gunnery scenario is summarised by the following table:

Official False Alarm Score	773	19 False Alarms per UXO Detected
Number of Items GTL Incorrectly Reported as UXO	276	7 False Alarms per UXO Detected
Number of Items GTL Correctly Reported as Non-UXO	408	GTL considers these were correctly reported
Number of UXO Reported as Non-UXO	3	All of these GTL understood were Non-UXO as they were rocket motors without their explosive warhead.

We consider a process which scores as a false alarm a target that was correctly reported as Non-UXO, to be a flawed process and that correctly typing a metallic object as Non-UXO is a positive achievement. We therefore conclude from this analysis that GTL's true false alarm rate on this Aerial Gunnery scenario was 7 false alarms per UXO detected and that this was achieved without reduction in the detection of UXO.

#### 4. CONCLUSIONS

Availability of the baseline data information has enabled the source of deficiencies in GTL's UXO detection performance to be clearly identified and these are identified below.

Inadequacies in the description provided to GTL of the Non-UXO baseline targets resulted in difficulty in drawing clear conclusions regarding detection and typing of these items.

The official policy of scoring metallic targets correctly reported as having sources that are Non-UXO led to a misleading measure of false alarm performance that penalised a positive achievement in typing technology.

Specific conclusions including solutions to observed deficiencies in the technology demonstrated are listed below focusing upon the three parameters of "detection", "typing" and "discrimination".

##### 4.1 Detection Performance

- The performance of the TM-4 $\varepsilon$  in detecting UXO targets can be improved by lowering the interpretation threshold. The implementation of recent improvements in processing the EM data enables the interpretation threshold to be lowered without increasing the false alarm rate.
- The performance of the magnetometer in detecting UXO targets can be improved at this locality by lowering the sensor elevation (and correspondingly reducing the sensor line separation). This is not a general conclusion because it applies only to situations where the source of geological interference is deeper than the targets of interest.
- An error in our algorithm the fusion of data from both the magnetometer and TM-4 $\varepsilon$  EM system was identified and rectified.
- In spite of the error in our algorithm the fusion of data from both the magnetometer and TM-4 $\varepsilon$  EM system produced a detection outcome in both the Aerial Gunnery and Artillery and Mortar scenarios that was better than that of either sensor in isolation.
- With the implementation of recent improvements in processing the EM data, GTL believe that the TM-4 $\varepsilon$  is now capable of detecting and interpreting 99% of the baseline Grenade and Sub-munition targets at this scenario leaving only those baseline targets that are non-metallic remaining undetected. Therefore the acquisition of magnetic data may not generally be considered cost-effective for this scenario.
- GTL believe that to be defined as a baseline UXO target a "rocket" had to include the explosive warhead and that this misunderstanding was the only reason we did not achieve a 100% UXO detection score on the Aerial Gunnery scenario.
- We are unable to draw conclusions regarding 6 of the 8 non-UXO targets that we failed to report at the Aerial Gunnery scenario due to inadequate description of what these items were. For example, if "building material" was solely non-metallic, our failure to report it would have been seen by us as a positive performance whereas if it included reo-bars for example at 0.23 m depth then failure to report this would be regarded as serious and requiring explanation.

### 3.3.2 False Alarms, Scenario 2: Artillery and Mortar

Analysis of the false alarms scored against GTL at the Artillery and Mortar scenario is summarised by the following table:

Official False Alarm Score	1209	20 False Alarms per UXO Detected
Number of Items GTL Incorrectly Reported as UXO	422	7 False Alarms per UXO Detected
Number of Items GTL Correctly Reported as Non-UXO	714	
Number of UXO Reported as Non-UXO	1	

We consider a process which scores as a false alarm a target that was correctly reported as Non-UXO, to be a flawed process and that correctly typing a metallic object as Non-UXO is a positive achievement. We therefore conclude from this analysis that GTL's true false alarm rate on this Artillery and Mortar scenario was 7 false alarms per UXO detected and that this was achieved at the expense of reducing the detection of UXO by 1 item.

### 3.3.3 False Alarms, Scenario 3: Grenades and Sub-munitions

Analysis of the false alarms scored against GTL at the Grenades and Sub-munitions scenario is summarised by the following table:

Official False Alarm Score	973	10 False Alarms per UXO Detected
Number of Items GTL Incorrectly Reported as UXO	928	10 False Alarms per UXO Detected
Number of Items GTL Correctly Reported as Non-UXO	0	
Number of UXO Reported as Non-UXO	0	

We conclude from this analysis that GTL's true false alarm rate on this Grenades and Sub-munitions scenario was 10 false alarms per UXO detected.

#### 4.2 Typing of Targets as UXO or Non-UXO

Because the TM-4 $\epsilon$  was demonstrated before its full potential for typing had been developed the approach taken for typing was of necessity, conservative. If a magnetic response did not fall clearly outside the range of expected responses for the baseline items then it was reported as "UXO". Similarly, if the TM-4 $\epsilon$  response did not depart clearly from that expected from a baseline target then it was reported as "UXO". With such elementary criteria upon which to base our typing it was not surprising that our reporting of UXO was relatively accurate while our reporting on Non-UXO was not. Improvements in the processing of TM-4 $\epsilon$  data have since been demonstrated at the JPG(IV) program.

#### 4.3 Discrimination Against False Alarms

We consider a process which scores as a false alarm a target that was correctly reported as Non-UXO, to be a flawed process and that correctly typing a metallic object as Non-UXO is a positive achievement. We therefore conclude from this analysis that:

- GTL's true false alarm rate on the Aerial Gunnery scenario was 7 false alarms per UXO detected (and not 19 as officially reported) and that this was achieved without reduction in the detection of UXO.
- GTL's true false alarm rate on this Artillery and Mortar scenario was 7 false alarms per UXO detected (and not 20 as officially reported) and that this was achieved at the expense of reducing the detection of UXO by 1 item.
- GTL's true false alarm rate on this Grenades and Sub-munitions scenario was 10 false alarms per UXO detected.

Improvements in the processing of TM-4 $\epsilon$  data have since been demonstrated at the JPG(IV) program and the application of this technology to discriminate against false alarms is expected to further improve the false alarm rate in the future.

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